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Memorandum

To/Attention	City of Cambridge	Date	July 23, 2014
From	IBI Group	Project No	36660
cc		Steno	tt
Subject	Cambridge Service Analysis - FINAL		

Project Understanding

Transit services in urban settings face a number of challenges due to space constraints, congestion, and delay, among other issues. The City of Cambridge engaged IBI Group to carry out an analysis of important bus routes (1, 69, 73, and 77) within the City limits to determine where these challenges are sufficient to warrant City initiatives to improve bus service, including implementing priority for buses at traffic signals (transit signal priority or TSP) or reserving space for buses only (such as queue jump lanes allowing buses to get a head start on other vehicles at traffic lights). This memorandum presents the methodology and results of that analysis.

Summary of Results

The results of this analysis indicate locations along the four bus routes where buses experience significant delay and/or reliability challenges. The table below identifies the ten worst ranking composite grades for travel time delay (both in terms of bus delay and passenger delay) and unreliability. For further definition of the measures used to reach these conclusions, as well as the analysis of each route identifying these areas for improvements, please see later sections of this memorandum.

Ten Worst Ranking Composite Grades

Route	Peak	Direction	From	To	Composite Grade
73	AM	Towards Harvard	Mt Auburn St @ Aberdeen Ave	Mt Auburn St @ Coolidge Ave	F
77	PM	From Harvard	Mass. Ave @ Exeter Park	Mass. Ave @ Porter Red Line Sta	F
1	PM	From Harvard	84 Mass. Ave	Mass. Ave @ Beacon St	F
77	AM	Towards Harvard	Mass. Ave @ Rindge Ave	Mass. Ave @ Walden St	F
1	PM	Towards Harvard	Mass. Ave @ Sidney St	Mass. Ave @ Prospect St	F
77	PM	From Harvard	Mass. Ave @ Cameron Ave	Mass. Ave @ Churchill Ave	E
77	PM	From Harvard	Mass. Ave @ Davenport St	Mass. Ave opp Walden St	E
69	PM	From Harvard	Cambridge St @ Fayette St	Cambridge St @ Hampshire St	E
73	AM	Towards Harvard	Mt Auburn St @ Coolidge Ave	Mt Auburn St opp Traill St	E
1	AM	From Harvard	84 Mass. Ave	Mass. Ave @ Beacon St	E

In addition to the ten worst ranking segments overall, IBI Group also looked at the top ten worst ranking segments either in terms of travel time or unreliability alone. The top ten worst ranking scores for excess bus travel time (later called Excess Running Time) mostly overlap with the top ten worst ranking composite scores. The four segments that do not overlap are listed below.

Worst Ranking Excess Running Time Grades (without overlap with Composite Grade ranking)

Route	Peak	Direction	From	To	Composite Grade
69	PM	Towards Harvard	Felton St @ Cambridge St	Quincy St @ Broadway opp Fogg Museum	E
1	PM	From Harvard	Mass. Ave @ Pleasant St	Mass. Ave @ Pearl St	E
77	AM	Towards Harvard	Mass. Ave @ Linnaean St	Mass. Ave @ Shepard St	D
77	AM	Towards Harvard	Mass. Ave @ Upland Rd	Mass. Ave @ Linnaean St	D

The top ten worst ranking grades for passenger travel time (the excess bus travel time multiplied by the number of passengers, called Excess Passenger Travel Time) entirely overlapped with the worst composite grades. The top ten worst ranking scores in terms of reliability varied more - only four of the ten overlapped with the worst composite grades. Because this provides a different perspective on problem areas, the worst ranking unreliability ratings that do not overlap with the composite grades are also listed in the table below.

Worst Ranking Unreliability Scores (without overlap with Composite Grade ranking)

Route	Peak	Direction	From	To	Composite Grade
77	PM	From Harvard	Mass. Ave @ Wendell St	Mass. Ave @ Exeter Park	E
73	AM	Towards Harvard	Mt Auburn St opp Homer Ave	Mt Auburn St @ Aberdeen Ave	C
77	AM	From Harvard	Mass. Ave @ Cameron Ave	Mass. Ave @ Churchill Ave	D
69	AM	From Harvard	Cambridge St @ Norfolk St	Cambridge St @ Windsor St	D
77	AM	Towards Harvard	Mass. Ave @ Hollis St	Mass. Ave @ Rindge Ave	E
77	AM	Towards Harvard	Mass. Ave opp Beech St	Mass. Ave @ Upland Rd	D

These results can be interpreted as providing an initial list of ‘low hanging fruit’, or near-term targets where there may be significant room for improvement. This does not mean that improvement will be achievable at all locations; rather, each location should be examined further before deciding whether to implement improvements. The segments with combined low composite grades, travel time, and unreliability grades are summarized below, organized and grouped by route, direction and severity as indicated by the ranking in the above tables:

- Route 73, eastbound towards Harvard, from Homer Ave to Aberdeen Ave and Traill St (near Fresh Pond Parkway).
- Route 77, northbound from Harvard, from Wendell St to Exeter Park and the Porter Sq Red Line Station. The segments between Cameron and Churchill Ave and between Davenport and Walden St. were indicated to be less severe (poorly performing for the composite score in the PM peak and for the unreliability score in the AM peak).
- Route 1, eastbound from Harvard, between 84 Mass Ave and Beacon St. performs consistently poorly in BOTH peaks. The segment between Pleasant St and Pearl St. ranks lower in terms of severity (the composite grade is not as bad as the others but the travel time ratings show issues).

- Route 77, southbound towards Harvard, from Hollis St to Rindge Ave and Walden St., and on the three segments between Beech St and Shepard St.
- Route 1, westbound towards Harvard, between Sidney St and Prospect St.
- Route 69, eastbound from Harvard, between Fayette St and Hampshire St as well as from Norfolk St to Windsor St.
- Route 69, westbound towards Harvard, between Felton St and Quincy St at Broadway opposite the Fogg Museum.

Measures

Three aspects of transit service quality were used to identify these locations for improvement. These are bus travel time, passenger travel time, and reliability of bus service. To assess these, three measures of effectiveness (MOEs) were established¹:

- *Excess running time (XRT)* refers to bus travel time in excess of an expected minimum. This measure captures the amount of delay for a bus. The cost of providing service is related to the number of hours vehicles spend on the road, so reducing excess travel time saves money by making operations more efficient.
- *Excess passenger travel time (XPT)* is the XRT applied to the number of passengers on the bus. Each passenger on each vehicle who experiences a travel time savings benefits from the time savings. This measure captures the amount of delay for *all* passengers on the buses in the analysis. It accounts for the fact that there is a greater overall benefit for every minute saved on a more heavily loaded bus than on a lightly loaded bus. 'Passenger' is abbreviated as 'pax' in some cases.
- *Unreliability* is estimated as the change in standard deviation of cumulative travel time (or 'Change in SDCTT'). This measure captures the unreliability or variability of bus service. The standard deviation provides a measure of the reliability of bus service, with a lower value indicating less variation in the travel times. When bus travel time are more reliable and less variable, passengers have a shorter average waiting time for the same average number of buses passing per hour.

The MOEs can all be estimated using data from the MBTA's Automatic Passenger Counters (APCs). These on-board devices count the number of passengers boarding and alighting a bus at each stop, and also provide the travel time from the time the door closes at a stop, to the time a bus starts moving, to the time the door opens again at the next stop. The time from when the bus starts moving away from a stop to the time when the door opens at the next stop constitutes a stop-to-stop 'segment' in this analysis. The boarding and alighting information also allows calculation of the passenger load (i.e. the number of passengers in the bus) after each stop.

¹ This approach was established at a meeting with City staff on May 23, 2014.

There are APC data for hundreds of trips in both the AM and PM weekday periods, providing a good dataset for bus performance during these times.²

The following sections further describe each MOE and how it was estimated, with some additional information in an appendix. The MOEs are also combined into a composite 'letter grade' rating system for each route segment. Finally, the results of the analysis for each route are described.

Excess Running Time (XRT)

Purpose: This measure captures the amount of delay for a bus.

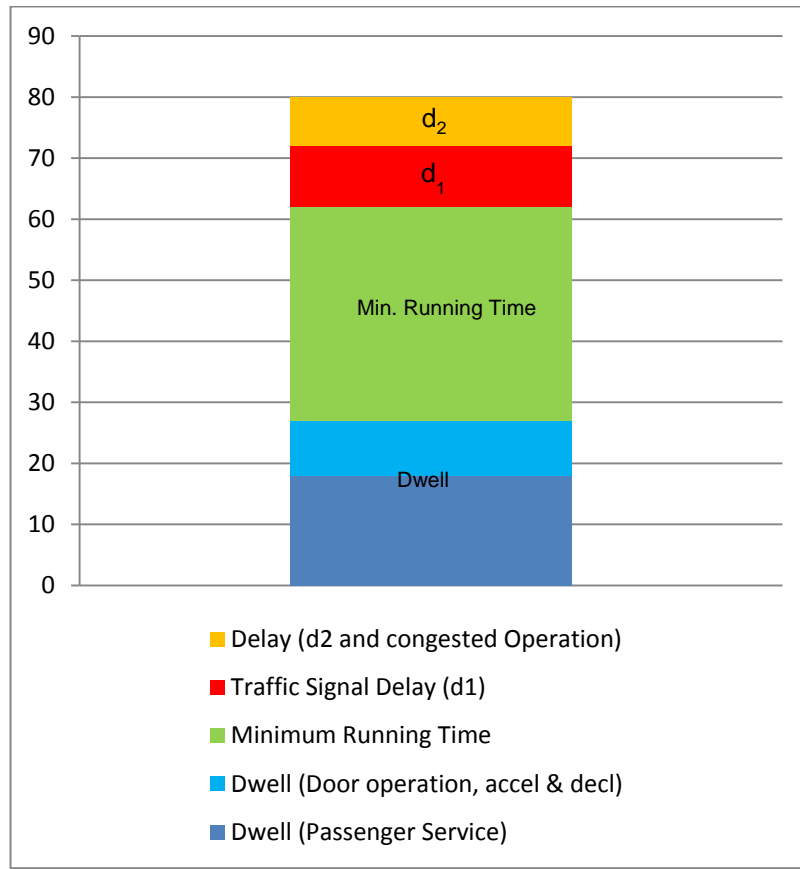
Excess running time (XRT) occurs when a bus takes longer to travel between stops than it 'should'. There are a number of components of travel time, which are described below and shown in Exhibit 1:

- the minimum travel time at a constant maximum permitted speed (e.g. the speed limit);
- the dwell time associated with passenger stops, including the time lost in slowing down to stop, the time to open the doors, allow passengers to board and alight, and close the doors, and the time lost in accelerating to speed again; and
- two types of traffic delay, including:
 - d_1 or control delay (i.e. delay from a traffic signal) that would be expected on average if there were no other traffic other than the bus, and
 - d_2 or delay attributable to the operation of other traffic, such as queuing from congestion.

Exhibit 1 shows these travel time components together, providing a sense of the relative sizes of each component for a hypothetical 'typical' segment. Both the absolute values and the proportions differ significantly among segments.

² Data were collected for trips made during the fall of 2013 for routes 69, 73, and 77. Because of recent changes in the stop configurations for route 1, the results for this route are based on data from the spring of 2014. Approximately 25 percent of MBTA buses are equipped with APCs. At least 200 observations were available for each route in each direction in each time period. AM peak is 7am – 9am and PM peak is 4pm – 6:30pm.

Exhibit 1: Typical Components of Bus Running Time (in seconds)



To identify areas where the City of Cambridge can make improvements, this analysis focuses on the traffic related delay, d_1 and d_2 , which include delay at traffic signals or due to congestion. Dwell times are determined principally by factors not under the City's control, such as passenger volumes and service frequency, and so are not included in the XRT measure.

All three MOEs, including XRT, are measured for both AM and PM peaks (7-9 am and 4-6:30 pm, respectively) and both directions of travel.

The XRT is measured as the difference between the median³ of the APC-recorded travel times of buses on a segment and a minimum or reference running time. This reference running time is the amount of time it 'should' take a bus to travel a segment with no other delays. Because travel conditions vary, the reference running time for each segment was established as the minimum of the following three values:

³ The median is used instead of the average so that the result is not overly influenced by outliers that were not removed in the process of cleaning the data, or by skewed data (i.e. data with a distribution that is not normal).

- The median running time observed in the early morning hours (between 6:00 AM and 7:00 AM);
- The median running time observed in the late evening hours (between 11:00 PM and midnight); and
- The minimum time that a 40-foot low floor MBTA bus would need to move from one stop to the next, while not exceeding a top speed of 35 mph.⁴

Any of these measures could be used as a minimum travel time; however, the observed travel times varied enough that in many cases use of a single measure was not consistent enough for the purposes of this analysis. The minimum of these three measures was found to provide a good estimate of the minimum feasible running time.

Almost any bus trip observed between the stops will take longer than the reference running time. This 'excess' time is likely to be perceived as delay, and will contribute to increasing operating costs, which are primarily driven by the hours buses spend on the road.

In this document XRT is represented in seconds per segment.

Excess Travel Time (XPT)

Purpose: This measure captures the amount of delay for passengers.

Although the XRT measure captures vehicle delay, it does not fully account for the impact of these delays on the traveling public. Each passenger on a bus is affected by the vehicle delay, and so the overall delay experienced by passengers is proportional to the number of passengers on the bus. Simply put, the overall passenger delay is greater for a crowded bus, than for a relatively empty bus.

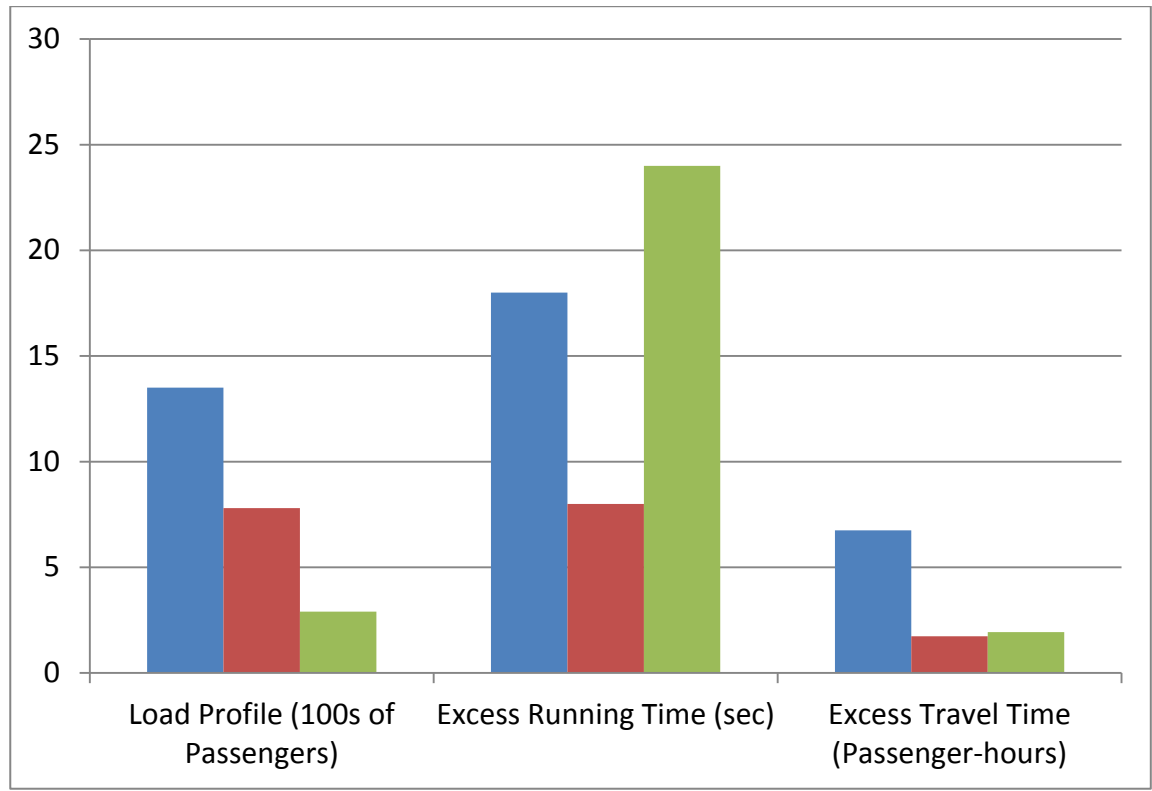
In addition, it is widely acknowledged that the time passengers spend traveling has an economic value; and so, the greater the delay, the more the cost, and vice versa. The excess travel time (XPT) MOE captures this effect at the passenger level.

To account for how passengers as a whole are affected, the number of passengers on a vehicle (i.e. the passenger load) must be considered in addition to the magnitude of the vehicle delay. The number of passengers (load) on a bus between stops can be estimated from APC data on boardings and alightings. The median passenger load on a segment is multiplied by the XRT to estimate the XPT. In this document, XPT is represented in passenger-minutes.

As shown in Exhibit 2, differences in average bus loading can result in XPT having different relative values on segments than XRT. In the hypothetical example shown in Exhibit 2, the green route segment has very high delays and so rates poorly in terms of XRT, but it affects few passengers and so would not be rated so severely in terms of XPT.

⁴ Estimated by a bus performance calculation spreadsheet developed by IBI Group.

Exhibit 2: XRT, Passenger Loads, and XPT for three Hypothetical Segments



Unreliability

Purpose: This measure captures the unreliability or variability of bus service.

Both passengers and transit operators (i.e. MBTA) are affected negatively by variability in travel times. For the operator, high variability in travel time requires additional recovery time in the schedule to accommodate late buses, driving up operating costs. As previously mentioned, operating costs are related to the number of hours vehicles and their operators spend on the road in service. For passengers, high variability is perceived as unreliability, and passengers may need to plan on longer travel times to be sure that they arrive on-time. In addition, when intervals between buses become erratic, passengers wait longer on average.

As a bus progresses along its route, variability increases because of unpredictable effects from traffic signals and other vehicles, even if buses always leave on-schedule. These effects can accumulate on the route, so that the variability introduced almost always⁵ persists and even increases along the route. It is also usually true that once variability is introduced to a route, opportunities to reduce it downstream are limited.

⁵ In some cases timetables may include mid-route recovery time; this can improve service regularity, but at the cost of increasing average travel time.

Another complicating factor reducing reliability is vehicle ‘bunching’, when buses travel close to each other. When a bus operates closer to the bus ahead, it picks up fewer passengers than usual, and tends to catch up even more to its leader. Similarly, a long interval between buses will tend to get longer as the follower picks up more than the average number of passengers.

The unreliability MOE is calculated as the change in standard deviation of cumulative travel (Change in SDCTT)⁶. The standard deviation of travel times⁷ is a commonly used measure for travel time variability. The more erratic a bus is, the higher the value of the standard deviation will be. The change in standard deviation of cumulative travel (SDCTT) is the difference between the standard deviation of cumulative travel time (excluding dwell time) and the same value at the previous stop. It measures the variability introduced by each segment from the previous segment.

In this document, the unreliability MOE is represented in seconds.

Rating of MOEs

For each MOE, ranges were established to map to six general conditions, and were associated with colors ranging from green to red in accordance with the severity of a service deficiency identified by that MOE. These ratings may also be related to qualitative descriptions (Excellent to Failing) and the letter grades ‘A’ to ‘F’ as follows:

- Excellent (dark green or ‘A’) – Delays (XRT and XPT) are generally not perceived by travelers, or the route segment causes less than a typical increase in variability in travel time (SDCTT).
- Good (light green or ‘B’) – Delays are not perceived as a problem or the segment does not introduce unexpected levels of variability.
- Satisfactory (yellow or ‘C’) – Delays are noticeable, or the segment introduces noticeable variability in travel times.
- Unsatisfactory (light orange or ‘D’) – Delays cause service to be perceived as slow for the prevailing conditions, or the segment introduces significant variability in travel times. *Conditions should be examined further to see whether there are opportunities for improvement.*
- Poor (dark orange or ‘E’) – Delays cause service to be perceived as very slow, or the segment introduces serious instability to the route’s operation downstream. *Opportunities for improvement should be identified.*
- Failing (red or ‘F’) – Delays in the segment, or the variability in travel times introduced in the segment, are serious and *warrant correction.*

⁶ In its work for York Region Transit’s VIVA bus rapid transit system north of Toronto, IBI Group had the opportunity to work with large APC datasets, leading to the development of benchmarks for how much the standard deviation of cumulative travel time (from the origin to any stop along the route) ‘should’ change from stop to stop. These benchmarks were adapted to this context for this analysis based on observations for Cambridge.

⁷ The formula for standard deviation of travel time is $\sqrt{\frac{\sum T_i^2 - [\sum T_i]^2}{N-1}}$, where T_i is the value of the i th of N observations of travel time.

For each MOE, rating ranges (shown in Exhibit 3) were established both by considering the typical observed range of each MOE for this dataset, as well as by building on IBI Group’s extensive research into transit operations throughout North America. The benchmarks apply to the measure for each stop-to-stop segment, excluding dwell time at the stops.

Exhibit 3: Rating Ranges for MOEs

Excess Vehicle Running Time (seconds)	Excess Passenger Travel Time (person-minutes)	Unreliability (seconds)
0 – 10	0 – 1.5	Less than 10
10 – 25	1.5 – 4.0	10 – 20
25 – 40	4.0 – 8.0	20 – 40
40 – 55	8.0 – 16.0	40 – 80
55 – 70	16.0 – 24.0	80 – 120
Greater than 70	Greater than 24.0	Greater than 120
N/A	N/A	N/A

In some of the tables and charts in this report, the color gray is used to indicate that the numerical value may not support the corresponding rating. This can happen in the first or last segment of a route, for instance, when the particulars of berthing buses at terminals may not follow patterns typical of stops en route.

The ranges for XRT are also not dissimilar to those for intersection Level of Service in the *Highway Capacity Manual*⁸. The ranges for *unreliability* (Change in SDCTT) are consistent with the general approach to using the standard deviation of travel time in the *Transit Capacity and Quality of Service Manual*⁹.

Composite Letter Grade

IBI Group developed a composite rating of the three MOEs so that most locations for improvement could be identified by a quick look at a single graphic. This composite rating was developed because a simple average of the ratings for each MOE would allow an excellent rating to obscure a failing one. For the composite grade, a very poor performance on only one of the three MOEs would have a more than proportional effect.

Appendix A presents how this composite measure was developed.

⁸ Transportation Research Board, Special Report 209, *Highway Capacity Manual*, Washington, DC, 2000, Exhibit 16-2.
⁹ Transit Cooperative Research Program, Report 100, *Transit Capacity and Quality of Service Manual*, Washington, DC, 2003, Exhibit 3-30.

Results

The following sections present the results of the analysis for each route. For each route, the results are described in the following order:

1. Composite Grade Summary: Combined low (D or worse) composite grades in both the AM and PM peaks.
2. Composite Grade PM Peak: Low composite grades in either direction in the PM peak. Specific MOEs that contribute to the low grade are discussed.
3. Composite Grade AM Peak: Low composite grades in either direction in the AM peak. Specific MOEs that contribute to the low grade are discussed.
4. Other MOE Ratings: If needed, other low ratings for any of the three MOEs that do not necessarily result in low composite grades in either the AM or PM peaks.

Although these results are first discussed in a narrative format, there are also maps for the composite ratings as well as tables showing the values for individual MOEs. Maps and tables are provided for each route in each direction for each peak.

Route 77

MBTA key bus route 77 extends 5.3 miles between Arlington Heights and Harvard Station via Massachusetts Avenue. About 2.3 miles of the route are in the City of Cambridge. Some short-turn trips operating as route 77A run between Harvard Station and the North Cambridge carhouse, and serve to move trolleybuses assigned to routes 71 and 73. All data in this report are from diesel buses operating on the entirety of route 77. Service operates every seven minutes in peak periods.

Results for Route 77

Composite Grade Summary:

In general, lower ratings occur in the direction of peak travel (toward Harvard in the AM and from Harvard in the PM). In the southbound (toward Harvard) direction, the segments between Beech St and Shepard St are the only ones that are rated D or worse in both the AM and PM peaks. In the northbound direction, Cameron Ave to Churchill Ave is the only segment that is D or worse in both peaks.

The only segment that that ranks D or worse in both directions (AM towards Harvard, and PM from Harvard) is Walden St to Rindge Ave, or vice versa.

Composite Grade PM Peak:

In the PM peak, the worst segments are in the northbound (from Harvard) direction, which is the peak travel direction. The worst (F) composite grade is between Exeter Park and Porter Red Line Station, with additional E segments between Wendell St and Exeter Park (where the unreliability is the worst), Davenport St and Walden St, and Cameron and Churchill Ave (the last two being where XPT is the worst of the three metrics). Other northbound segments that warrant investigation include Walden St to Rindge Ave and Churchill Ave to Gladstone St, where the composite rating is D primarily due to XPT.

In the PM peak southbound direction additional D segments include those between Beech Street and Shepard St, primarily due to XRT and XPT.

Composite Grade AM Peak:

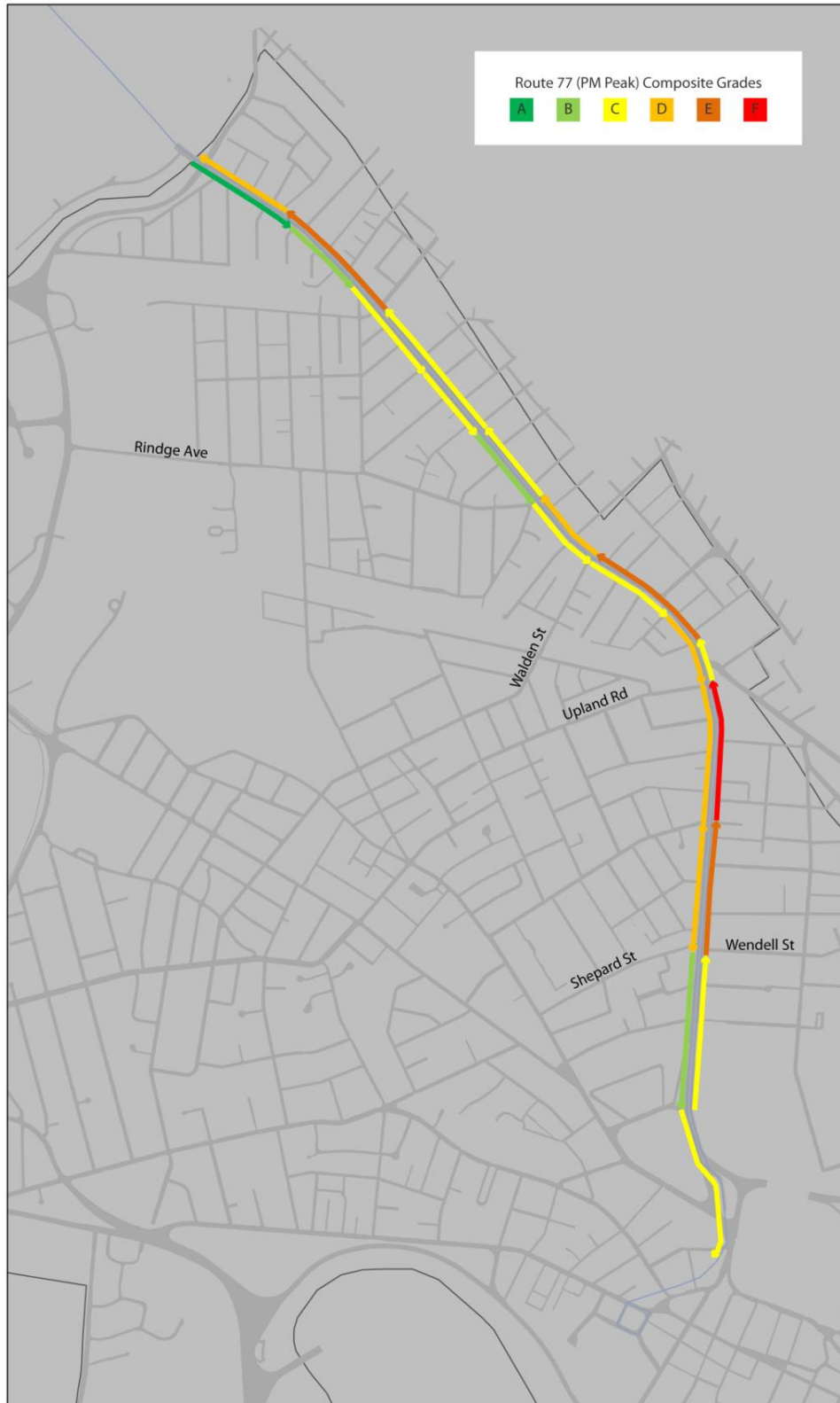
In the AM peak, the southbound (towards Harvard) direction has more issues, with most of the composite grades being D or worse. This is again the peak commuting direction. The worst composite grade (F) is between Rindge Ave and Walden St, with the second worst (E) on the segment upstream (Hollis St to Rindge Ave). All low composite grades are primarily due to the XRT and XPT MOEs (unreliability is never below a C).

In the AM peak northbound direction, there is only one composite grade of D between Cameron and Churchill Ave. The worst MOE on this segment is unreliability.

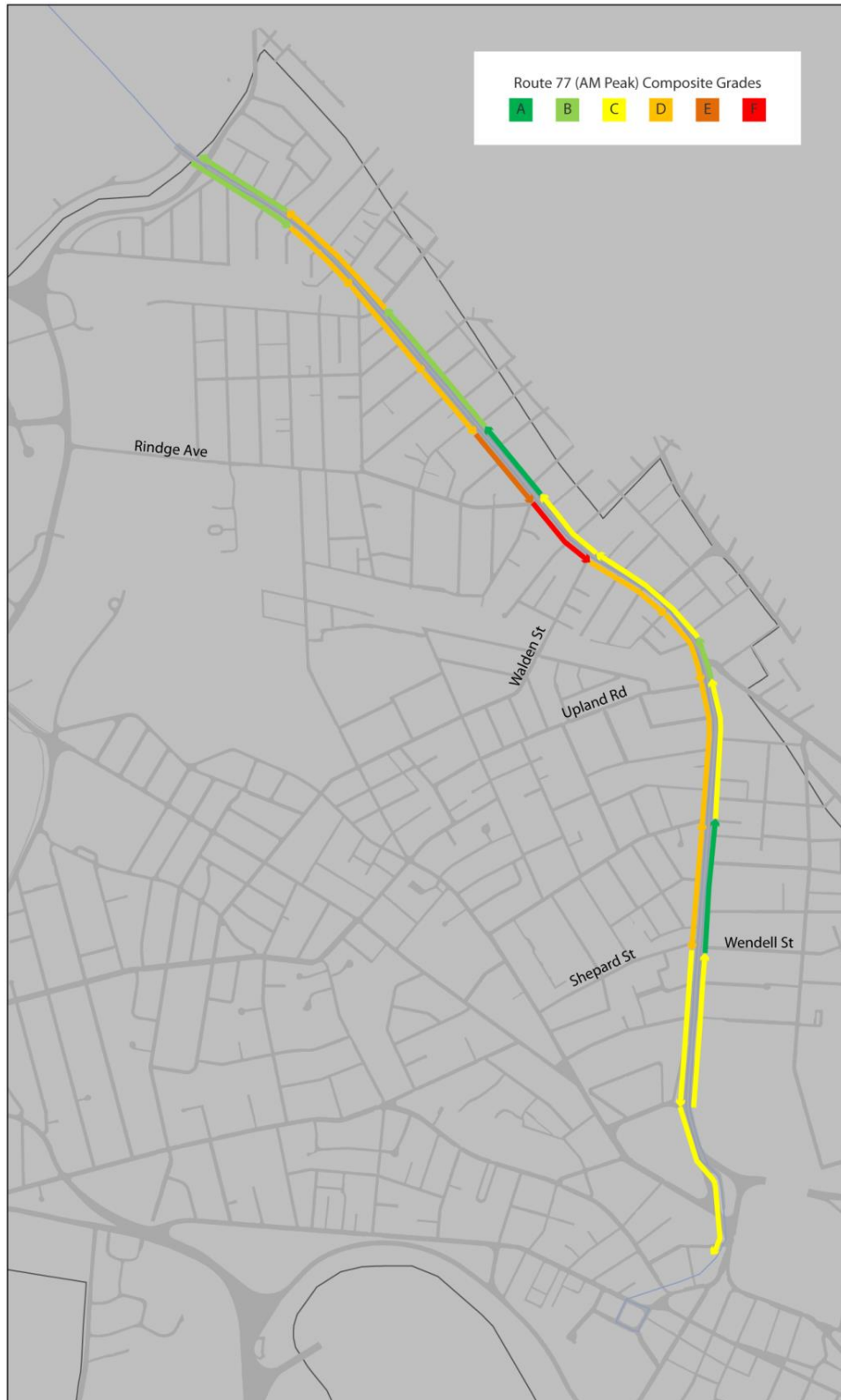
Other MOE Ratings:

There are only a few cases where an MOE rates D or worse while the composite grade is C or better. These include the XPT between Rindge Ave and Walden St in the PM peak towards Harvard, and the XPT between Davenport St and Walden St in the AM peak from Harvard. This supports further focus on the area around Walden St for general improvements.

Route 77 PM Peak



Route 77 AM Peak



Route 77 PM Peak – From Harvard

Place	Segment Start	Segment End	Median Running Time	Reference Running Time	Excess Running Time	Median Load	Excess Pax Time	Unreliability	Composite Grade
Harvard Square	Harvard Upper Busway	Mass. Ave opp Waterhouse St	95	51.1	43.9	23	16.8	30.03	
	Mass. Ave opp Waterhouse St	Mass. Ave @ Wendell St	56	44.3	11.7	25	4.9	25.34	C
	Mass. Ave @ Wendell St	Mass. Ave @ Exeter Park	69	40.3	28.7	25.5	12.2	95.62	E
Porter Square	Mass. Ave @ Exeter Park	Mass. Ave @ Porter Red Line Sta	164	42.4	121.6	25	50.7	56.69	F
	Mass. Ave @ Porter Red Line Sta	Mass. Ave @ Davenport St	35	18.0	16.5	29	8.0	1.02	C
	Mass. Ave @ Davenport St	Mass. Ave opp Walden St	86	26.0	60.0	33	33.0	13.18	E
	Mass. Ave opp Walden St	Mass. Ave opp Rindge Ave	51	17.5	33.5	33	18.4	6.94	D
	Mass. Ave opp Rindge Ave	Mass. Ave @ Dover St	35	26.0	9.0	33	5.0	11.39	C
	Mass. Ave @ Dover St	Mass. Ave @ Cameron Ave	48	35.0	12.5	33	6.9	26.54	C
	Mass. Ave @ Cameron Ave	Mass. Ave @ Churchill Ave	86	34.0	52.0	31	26.9	46.00	E
	Mass. Ave @ Churchill Ave	Mass. Ave @ Gladstone St	52	18.0	34.0	28	15.9	15.12	D
	Cambridge Line	Mass. Ave @ Gladstone St	Mass. Ave opp Boulevard Rd	69	18.0	51.0	28	23.8	6.44
Mass. Ave opp Boulevard Rd		Mass. Ave @ Teel St	18	17.0	1.0	28	0.5	0.64	A
Mass. Ave @ Teel St		Mass. Ave @ Windsor St	26	17.0	9.0	27	4.1	-2.64	B
Mass. Ave @ Windsor St		Mass. Ave opp Lake St	52	26.0	26.0	27	11.7	-11.30	C
Mass. Ave opp Lake St		Mass. Ave @ Harlow St	34	18.0	16.0	26.5	7.1	-3.22	C
Mass. Ave @ Harlow St		Mass. Ave @ Foster St	17	17.0	0.0	26	0.0	3.95	A
Mass. Ave @ Foster St		Mass. Ave @ Palmer St	35	26.0	9.0	25	3.8	2.61	B
Mass. Ave @ Palmer St		Mass. Ave @ Franklin St	17	9.0	8.0	26	3.5	-2.75	B
Mass. Ave @ Franklin St		Mass. Ave @ Medford St	43	26.0	17.0	25	7.1	1.03	C
Mass. Ave @ Medford St		Mass. Ave @ Mystic St	43	26.0	17.0	22.5	6.4	6.49	C
Mass. Ave @ Mystic St		Mass. Ave @ Central St	39	26.0	13.0	20	4.3	-0.78	C
Mass. Ave @ Central St		Opp 818 Mass Ave	43	25.5	17.5	18.5	5.4	4.65	C
Opp 818 Mass Ave		905 Mass. Ave	65	26.0	39.0	14.5	9.4	0.21	C
905 Mass. Ave		Mass. Ave @ Prentiss Rd	35	17.0	18.0	14	4.2	-0.09	C
Mass. Ave @ Prentiss Rd		Mass. Ave @ Brattle St	26	17.0	9.0	12	1.8	-0.91	B
Mass. Ave @ Brattle St		Mass. Ave @ Hobbs Ct	35	25.0	10.0	10	1.7	1.85	B
Mass. Ave @ Hobbs Ct		Mass. Ave opp Appleton St	35	25.0	10.0	8	1.3	2.98	B
Mass. Ave opp Appleton St	Mass. Ave opp Daniels St	26	26.0	0.0	8	0.0	0.65	A	
Mass. Ave opp Daniels St	Mass. Ave @ Park Ave	26	17.0	9.0	7	1.1	-0.67	A	
Arlington Heights	Mass. Ave @ Park Ave	Arlington Heights Busway	43	26.0	17.0	4	1.1	3.94	

Route 77 PM Peak – Towards Harvard

Place	Segment Start	Segment End	Median Running Time	Reference Running Time	Excess Running Time	Median Load	Excess Pax Time	Unreliability	Composite Grade
Arlington Heights	Arlington Heights Busway	Mass. Ave @ Park Ave	61	28.7	31.8	3	1.6	44.81	
	Mass. Ave @ Park Ave	Mass. Ave @ Daniels St	43	26.0	17.0	5	1.4	1.73	B
	Mass. Ave @ Daniels St	Mass. Ave @ Appleton St	26	17.0	9.0	5	0.8	1.68	A
	Mass. Ave @ Appleton St	Mass. Ave @ Quincy St	35	26.0	9.0	5	0.8	2.52	A
	Mass. Ave @ Quincy St	Mass. Ave @ Menotomy Rd	35	17.0	18.0	6	1.8	5.91	B
	Mass. Ave @ Menotomy Rd	Mass. Ave @ Mt Vernon St	26	17.0	9.0	7	1.1	1.72	A
	Mass. Ave @ Mt Vernon St	Mass. Ave @ Lockeland Ave	74	25.5	48.5	7	5.7	24.10	D
	Mass. Ave @ Lockeland Ave	Mass. Ave @ Newman Way	30	17.0	13.0	8.5	1.8	3.15	B
	Mass. Ave @ Newman Way	Mass. Ave @ Academy St	60	26.0	34.0	9	5.1	1.46	C
	Mass. Ave @ Academy St	Mass. Ave @ Library Way	35	17.0	17.5	10	2.9	18.87	B
	Mass. Ave @ Library Way	Mass. Ave @ Broadway	69	38.2	30.8	11	5.6	15.01	C
	Mass. Ave @ Broadway	Mass. Ave @ Avon Pl	17	9.0	8.0	10	1.3	-1.52	A
	Mass. Ave @ Avon Pl	Mass. Ave @ Wyman Terr	18	17.0	1.0	10	0.2	-0.26	A
	Mass. Ave @ Wyman Terr	Mass. Ave @ Linwood St	26	17.0	9.0	11	1.7	2.71	B
	Mass. Ave @ Linwood St	260 Mass. Ave	26	17.0	9.0	12	1.8	0.88	B
	260 Mass. Ave	Mass. Ave @ Lake St	26	17.0	9.0	13	2.0	5.89	B
	Mass. Ave @ Lake St	Mass. Ave @ Milton St	43	18.0	25.0	13	5.4	0.02	C
	Mass. Ave @ Milton St	Mass. Ave @ Thorndike St	26	18.0	8.0	14	1.9	3.61	B
	Mass. Ave @ Thorndike St	Mass. Ave @ Lafayette St	26	13.0	13.0	13	2.8	0.91	B
Cambridge Line	Mass. Ave @ Lafayette St	Mass. Ave @ Columbus Ave	43	26.0	17.0	14	4.0	4.93	B
	Mass. Ave @ Columbus Ave	Mass. Ave @ Cottage Park Ave	26	30.8	0.0	14	0.0	-0.23	A
	Mass. Ave @ Cottage Park Ave	Mass. Ave @ Cedar St	34	26.0	8.0	14	1.9	3.87	B
	Mass. Ave @ Cedar St	Mass. Ave @ Norris St	43	26.0	17.0	15	4.3	7.11	C
	Mass. Ave @ Norris St	Mass. Ave @ Hollis St	34	17.0	17.0	16	4.5	1.24	C
	Mass. Ave @ Hollis St	Mass. Ave @ Rindge Ave	26	17.0	9.0	16	2.4	-1.86	B
	Mass. Ave @ Rindge Ave	Mass. Ave @ Walden St	61	26.0	35.0	16	9.3	4.53	C
Porter Square	Mass. Ave @ Walden St	Mass. Ave opp Beech St	43	26.0	17.0	17	4.8	-1.71	C
	Mass. Ave opp Beech St	Mass. Ave @ Upland Rd	56	26.0	29.5	17	8.4	10.22	D
	Mass. Ave @ Upland Rd	Mass. Ave @ Linnaean St	100	43.7	55.8	13	12.1	3.93	D
	Mass. Ave @ Linnaean St	Mass. Ave @ Shepard St	95	35.0	60.0	13	13.0	10.39	D
	Mass. Ave @ Shepard St	Mass. Ave @ Waterhouse St	48	35.0	12.5	13.5	2.8	6.03	B
	Mass. Ave @ Waterhouse St	Harvard Lower Busway	78	53.5	24.5	13.5	5.5	1.46	C
Harvard Square	Harvard Lower Busway	Eliot St @ Bennett St	164	43.0	121.0	2	4.0	126.01	

Route 77 AM Peak – From Harvard

Place	Segment Start	Segment End	Median Running Time	Reference Running Time	Excess Running Time	Median Load	Excess Pax Time	Unreliability	Composite Grade
Harvard Square	Harvard Upper Busway	Mass. Ave opp Waterhouse St	69	51.1	17.9	9	2.7	22.15	
	Mass. Ave opp Waterhouse St	Mass. Ave @ Wendell St	69	44.3	24.7	10	4.1	17.78	C
	Mass. Ave @ Wendell St	Mass. Ave @ Exeter Park	43	40.3	2.7	11	0.5	3.40	A
Porter Square	Mass. Ave @ Exeter Park	Mass. Ave @ Porter Red Line Sta	77	42.4	34.6	12	6.9	19.53	C
	Mass. Ave @ Porter Red Line Sta	Mass. Ave @ Davenport St	35	18.0	17.0	14	4.0	8.39	B
	Mass. Ave @ Davenport St	Mass. Ave opp Walden St	61	26.0	35.0	16	9.3	8.03	C
	Mass. Ave opp Walden St	Mass. Ave opp Rindge Ave	43	17.5	25.5	15	6.4	1.11	C
	Mass. Ave opp Rindge Ave	Mass. Ave @ Dover St	26	26.0	0.0	14.5	0.0	6.25	A
	Mass. Ave @ Dover St	Mass. Ave @ Cameron Ave	43	35.0	8.0	16	2.1	16.01	B
	Mass. Ave @ Cameron Ave	Mass. Ave @ Churchill Ave	56	34.0	22.0	15	5.5	70.09	D
Cambridge Line	Mass. Ave @ Churchill Ave	Mass. Ave @ Gladstone St	35	18.0	16.5	12	3.3	5.95	B
	Mass. Ave @ Gladstone St	Mass. Ave opp Boulevard Rd	30	18.0	12.0	12	2.4	0.45	B
	Mass. Ave opp Boulevard Rd	Mass. Ave @ Teel St	34	17.0	17.0	11	3.1	0.46	B
	Mass. Ave @ Teel St	Mass. Ave @ Windsor St	26	17.0	9.0	14.5	2.2	2.63	B
	Mass. Ave @ Windsor St	Mass. Ave opp Lake St	43	26.0	17.0	15	4.3	3.18	C
	Mass. Ave opp Lake St	Mass. Ave @ Harlow St	26	18.0	8.0	16	2.1	4.43	B
	Mass. Ave @ Harlow St	Mass. Ave @ Foster St	17	17.0	0.0	18	0.0	-0.21	A
	Mass. Ave @ Foster St	Mass. Ave @ Palmer St	34	26.0	8.0	18	2.4	2.11	B
	Mass. Ave @ Palmer St	Mass. Ave @ Franklin St	18	9.0	9.0	17	2.6	1.03	B
	Mass. Ave @ Franklin St	Mass. Ave @ Medford St	52	26.0	26.0	17.5	7.6	7.94	C
	Mass. Ave @ Medford St	Mass. Ave @ Mystic St	43	26.0	17.0	19	5.4	2.46	C
	Mass. Ave @ Mystic St	Mass. Ave @ Central St	43	26.0	17.0	16	4.5	-2.01	C
	Mass. Ave @ Central St	Opp 818 Mass Ave	52	25.5	26.5	16	7.1	4.03	C
	Opp 818 Mass Ave	905 Mass. Ave	52	26.0	26.0	9.5	4.1	9.19	C
	905 Mass. Ave	Mass. Ave @ Prentiss Rd	26	17.0	9.0	8	1.2	1.41	A
	Mass. Ave @ Prentiss Rd	Mass. Ave @ Brattle St	26	17.0	9.0	8	1.2	-0.03	A
	Mass. Ave @ Brattle St	Mass. Ave @ Hobbs Ct	34	25.0	9.0	6	0.9	-0.03	A
Mass. Ave @ Hobbs Ct	Mass. Ave opp Appleton St	34	25.0	9.0	6	0.9	0.53	A	
Mass. Ave opp Appleton St	Mass. Ave opp Daniels St	26	26.0	0.0	4	0.0	2.29	A	
Mass. Ave opp Daniels St	Mass. Ave @ Park Ave	25	17.0	8.0	4	0.5	5.97	A	
Arlington Heights	Mass. Ave @ Park Ave	Arlington Heights Busway	43	26.0	17.0	3	0.9	19.33	

Route 77 AM Peak – Towards Harvard

Place	Segment Start	Segment End	Median Running Time	Reference Running Time	Excess Running Time	Median Load	Excess Pax Time	Unreliability	Composite Grade
Arlington Heights	Arlington Heights Busway	Mass. Ave @ Park Ave	35	28.7	6.3	3	0.3	26.07	
	Mass. Ave @ Park Ave	Mass. Ave @ Daniels St	35	26.0	9.0	6	0.9	1.48	A
	Mass. Ave @ Daniels St	Mass. Ave @ Appleton St	25	17.0	8.0	7	0.9	0.93	A
	Mass. Ave @ Appleton St	Mass. Ave @ Quincy St	35	26.0	9.0	10	1.5	5.07	B
	Mass. Ave @ Quincy St	Mass. Ave @ Menotomy Rd	35	17.0	18.0	11	3.3	9.66	B
	Mass. Ave @ Menotomy Rd	Mass. Ave @ Mt Vernon St	26	17.0	9.0	13	2.0	6.28	B
	Mass. Ave @ Mt Vernon St	Mass. Ave @ Lockeland Ave	43	25.5	17.5	17	5.0	20.32	C
	Mass. Ave @ Lockeland Ave	Mass. Ave @ Newman Way	34	17.0	17.0	15	4.3	10.36	C
	Mass. Ave @ Newman Way	Mass. Ave @ Academy St	35	26.0	9.0	15	2.3	2.15	B
	Mass. Ave @ Academy St	Mass. Ave @ Library Way	26	17.0	9.0	17.5	2.6	6.20	B
	Mass. Ave @ Library Way	Mass. Ave @ Broadway	69	38.2	30.8	18.5	9.5	14.45	D
	Mass. Ave @ Broadway	Mass. Ave @ Avon Pl	17	9.0	8.0	19	2.5	1.80	B
	Mass. Ave @ Avon Pl	Mass. Ave @ Wyman Terr	17	17.0	0.0	19	0.0	1.95	A
	Mass. Ave @ Wyman Terr	Mass. Ave @ Linwood St	25	17.0	8.0	19	2.5	0.88	B
	Mass. Ave @ Linwood St	260 Mass. Ave	26	17.0	9.0	22	3.3	2.30	B
	260 Mass. Ave	Mass. Ave @ Lake St	35	17.0	18.0	23	6.9	4.95	C
	Mass. Ave @ Lake St	Mass. Ave @ Milton St	35	18.0	17.0	27	7.7	6.89	C
	Mass. Ave @ Milton St	Mass. Ave @ Thorndike St	48	18.0	29.5	28	13.8	23.24	D
	Mass. Ave @ Thorndike St	Mass. Ave @ Lafayette St	78	13.0	65.0	28	30.3	16.44	E
Cambridge Line	Mass. Ave @ Lafayette St	Mass. Ave @ Columbus Ave	69	26.0	43.0	29	20.8	14.74	D
	Mass. Ave @ Columbus Ave	Mass. Ave @ Cottage Park Ave	35	30.8	4.2	29.5	2.1	0.84	B
	Mass. Ave @ Cottage Park Ave	Mass. Ave @ Cedar St	52	26.0	26.0	33	14.3	17.19	D
	Mass. Ave @ Cedar St	Mass. Ave @ Norris St	69	26.0	43.0	32	22.9	8.80	D
	Mass. Ave @ Norris St	Mass. Ave @ Hollis St	52	17.0	35.0	32.5	19.0	21.35	D
	Mass. Ave @ Hollis St	Mass. Ave @ Rindge Ave	61	17.0	43.5	33	23.9	34.61	E
	Mass. Ave @ Rindge Ave	Mass. Ave @ Walden St	103	26.0	77.0	34	43.6	22.64	F
Porter Square	Mass. Ave @ Walden St	Mass. Ave opp Beech St	65	26.0	39.0	35.5	23.1	17.74	D
	Mass. Ave opp Beech St	Mass. Ave @ Upland Rd	43	26.0	17.0	34	9.6	33.03	D
	Mass. Ave @ Upland Rd	Mass. Ave @ Linnaean St	78	43.7	33.8	22.5	12.7	19.25	D
	Mass. Ave @ Linnaean St	Mass. Ave @ Shepard St	78	35.0	43.0	23	16.5	0.69	D
	Mass. Ave @ Shepard St	Mass. Ave @ Waterhouse St	52	35.0	17.0	23	6.5	-4.74	C
	Mass. Ave @ Waterhouse St	Harvard Lower Busway	78	53.5	24.5	19	7.8	5.02	C
Harvard Square	Harvard Lower Busway	Eliot St @ Bennett St	78	43.0	35.0	2	1.2	48.22	

Route 73

MBTA key route 73 extends 3.9 miles between Waverley Square and Harvard Station via Trapelo Road, Belmont Street, and Mount Auburn Street. It operates in conjunction with key route 71, and is virtually contiguous with it for 1.7 miles in the City of Cambridge. Both routes 71 and 73 are normally operated with electric trolleybuses, which are not equipped with APCs. However, during the fall of 2013, route 73 was operated with diesel buses because of construction work, so APC data were available. Service operates every five to ten minutes during peak periods.

Results for Route 73

Composite Grade Summary:

In the AM and PM peak commute directions (towards Harvard and from Harvard, respectively), the analysis shows that the segments more or less between Aberdeen and Coolidge should be a target for improvements. Otherwise, most segments have a composite rating of C or better, except in the AM Peak towards Harvard.

Composite Grade PM Peak:

In the PM peak, the only D ratings for the composite score in the westbound direction (from Harvard) are on the two segments between Coolidge Ave and Homer Ave, primarily due to an XPT rating of D or E combined with only slightly worse than usual XRT (C compared to B) and unreliability (B compared to A) ratings. The eastbound direction (towards Harvard) has no composite score worse than C.

Composite Grade AM Peak:

In the AM peak, composite scores show that the worst segments are in the eastbound peak commuting direction. Aberdeen Ave to Coolidge Ave has a composite score of F as well as Fs for all individual MOEs. Coolidge Ave to Traill St. is rated an E primarily due to XPT. Other segments with D grades in the eastbound direction, primarily because of the XPT, are Cushing St to Homer Ave and Sparks St to Brewer St. In the westbound direction, no segments rank worse than C for the composite score.

Other MOE Ratings:

In the PM peak westbound direction, while most segments have composite grades of C or better, there are a number of segments between Ash St and Coolidge Ave that have XPT ratings of D while the other MOEs are B or A. Passenger loads are high in this direction, so a small XRT can lead to an unsatisfactory XPT.

In the AM peak eastbound direction, only one segment, Traill St to Coolidge Ave, has an XPT rating of D.

Route 73 PM Peak



Route 73 AM Peak



Route 73 PM Peak– From Harvard

Place	Segment Start	Segment End	Median Running Time	Reference Running Time	Excess Running Time	Median Load	Excess Pax Time	Unreliability	Composite Grade
Harvard Square	Harvard Upper Busway	Mt Auburn St @ Story St	242	42.8	199.2	28	93.0	70.21	
	Mt Auburn St @ Story St	Mt Auburn St @ Ash St	26	21.0	5.0	34.5	2.9	6.81	B
	Mt Auburn St @ Ash St	Mt Auburn St @ Sparks St	52	35.0	17.0	34.5	9.8	-0.01	C
	Mt Auburn St @ Sparks St	Mt Auburn St @ Longfellow Rd	34	17.5	16.5	34.5	9.5	3.35	C
	Mt Auburn St @ Longfellow Rd	Mt Auburn St @ Traill St	26	9.0	17.0	33	9.4	1.80	C
	Mt Auburn St @ Traill St	Mt Auburn St opp Coolidge Ave	61	34.0	27.0	33	14.8	1.30	C
	Mt Auburn St opp Coolidge Ave	Mt Auburn St @ Aberdeen Ave	78	39.0	39.0	31	20.2	16.91	D
	Mt Auburn St @ Aberdeen Ave	Mt Auburn St @ Homer Ave	61	32.3	28.2	29	13.7	12.18	D
	Mt Auburn St @ Homer Ave	Belmont St @ Cushing St	26	21.5	4.5	26.5	2.0	4.37	B
	Belmont St @ Cushing St	Belmont St @ Sullivan Rd	17	17.0	0.0	26.5	0.0	3.38	A
Cambridge Line	Belmont St @ Sullivan Rd	Belmont St @ Oxford Ave	18	13.0	4.5	24.5	1.8	3.38	B
	Belmont St @ Oxford Ave	Belmont St @ Marion Rd	44	17.0	26.5	24.5	10.8	6.14	C
	Belmont St @ Marion Rd	Belmont St @ Falmouth St	43	29.9	13.1	20	4.4	9.65	C
	Belmont St @ Falmouth St	Belmont St @ School St	26	17.0	9.0	19	2.9	3.71	B
	Belmont St @ School St	Belmont St @ Payson Rd	26	21.5	4.5	16.5	1.2	10.16	B
	Belmont St @ Payson Rd	Belmont St @ Oakley Rd	26	17.0	9.0	15	2.3	9.58	B
	Belmont St @ Oakley Rd	Trapelo Rd @ Oak Ave	26	17.0	9.0	13	2.0	18.38	B
	Trapelo Rd @ Oak Ave	Trapelo Rd @ Common St - Cushing Square	52	34.5	17.5	12.5	3.6	23.62	C
	Trapelo Rd @ Common St - Cushing Square	Trapelo Rd opp Poplar St	69	34.7	34.3	10.5	6.0	4.58	C
	Trapelo Rd opp Poplar St	Trapelo Rd @ Slade St	35	26.0	9.0	10	1.5	4.77	B
	Trapelo Rd @ Slade St	Trapelo Rd opp Walnut St	18	18.0	0.0	7.5	0.0	3.08	A
	Trapelo Rd opp Walnut St	Trapelo Rd @ Beech St	22	9.0	12.5	7.5	1.6	0.60	B
	Trapelo Rd @ Beech St	Trapelo Rd @ Hawthorne St	17	8.0	9.0	6.5	1.0	-0.99	A
	Trapelo Rd @ Hawthorne St	Trapelo Rd @ Waverley St	17	17.0	0.0	5	0.0	2.45	A
Waverly Square	Trapelo Rd @ Waverley St	Church St @ Lexington St	35	18.0	17.0	5	1.4	4.81	

Route 73 PM Peak– Towards Harvard

Place	Segment Start	Segment End	Median Running Time	Reference Running Time	Excess Running Time	Median Load	Excess Pax Time	Unreliability	Composite Grade
Waverly Square	Church St @ Lexington St	Trapelo Rd @ Sycamore St	35	34.5	0.5	5.5	0.0	36.20	
	Trapelo Rd @ Sycamore St	Trapelo Rd @ Beech St	34	17.0	17.0	6	1.7	2.45	B
	Trapelo Rd @ Beech St	Trapelo Rd @ Walnut St	26	18.0	8.0	6	0.8	0.90	A
	Trapelo Rd @ Walnut St	Trapelo Rd @ Bartlett Ave	34	25.5	8.5	7	1.0	4.90	A
	Trapelo Rd @ Bartlett Ave	Trapelo Rd @ Poplar St	26	18.0	8.0	7	0.9	4.92	A
	Trapelo Rd @ Poplar St	Trapelo Rd @ Common St - Cushing Square	26	17.0	9.0	7	1.1	-0.61	A
	Trapelo Rd @ Common St - Cushing Square	36 Trapelo Rd	30	26.0	4.0	8	0.5	4.45	A
	36 Trapelo Rd	Trapelo Rd @ Belmont St - Benton Square	34	25.5	8.5	8	1.1	3.89	A
	Trapelo Rd @ Belmont St - Benton Square	395 Belmont St	18	13.0	5.0	8	0.7	2.82	A
	395 Belmont St	Belmont St opp Payson St	17	17.0	0.0	8	0.0	0.10	A
	Belmont St opp Payson St	Belmont St @ Carver Rd	18	13.0	5.0	8	0.7	0.21	A
	Belmont St @ Carver Rd	Belmont St @ Winsor Ave	18	9.0	9.0	8	1.2	6.07	A
	Belmont St @ Winsor Ave	Belmont St @ Woodleigh Rd	26	17.0	9.0	8	1.2	0.44	A
	Belmont St @ Woodleigh Rd	Belmont St @ Templeton Pkwy	34	17.0	17.0	8	2.3	6.94	B
	Belmont St @ Templeton Pkwy	Belmont St @ Prentiss St	44	18.0	26.0	8	3.5	6.88	C
Cambridge Line	Belmont St @ Prentiss St	Belmont @ Brimmer St	26	17.0	9.0	9	1.4	2.53	A
	Belmont @ Brimmer St	Belmont St opp Cushing St	26	17.0	9.0	9	1.4	0.25	A
	Belmont St opp Cushing St	Mt Auburn St opp Homer Ave	61	36.8	24.2	9	3.6	5.03	B
	Mt Auburn St opp Homer Ave	Mt Auburn St @ Aberdeen Ave	18	13.0	5.0	10	0.8	2.39	A
	Mt Auburn St @ Aberdeen Ave	Mt Auburn St @ Coolidge Ave	52	46.7	5.3	11	1.0	-0.14	A
	Mt Auburn St @ Coolidge Ave	Mt Auburn St opp Traill St	60	34.5	25.5	12	5.1	4.20	C
	Mt Auburn St opp Traill St	Mt Auburn St @ Mt Auburn Hospital	35	26.0	9.0	12	1.8	2.09	B
	Mt Auburn St @ Mt Auburn Hospital	Mt Auburn St opp Sparks St	26	17.5	8.5	16	2.3	2.71	B
	Mt Auburn St opp Sparks St	Mt Auburn St @ Brewer St	77	48.8	28.2	17	8.0	8.38	C
	Mt Auburn St @ Brewer St	Mt Auburn St @ University Rd	43	24.9	18.1	17	5.1	0.00	C
Harvard Square	Mt Auburn St @ University Rd	Harvard Upper Busway @ Red Line	35	26.0	9.0	14	2.1	1.82	

Route 73 AM Peak– From Harvard

Place	Segment Start	Segment End	Median Running Time	Reference Running Time	Excess Running Time	Median Load	Excess Pax Time	Unreliability	Composite Grade
Harvard Square	Harvard Upper Busway	Mt Auburn St @ Story St	276	42.8	233.2	12	46.6	127.57	
	Mt Auburn St @ Story St	Mt Auburn St @ Ash St	18	21.0	0.0	17	0.0	1.60	A
	Mt Auburn St @ Ash St	Mt Auburn St @ Sparks St	43	35.0	8.0	17	2.3	0.29	B
	Mt Auburn St @ Sparks St	Mt Auburn St @ Longfellow Rd	34	17.5	16.5	17	4.7	1.99	C
	Mt Auburn St @ Longfellow Rd	Mt Auburn St @ Traill St	18	9.0	9.0	15	2.3	-4.32	B
	Mt Auburn St @ Traill St	Mt Auburn St opp Coolidge Ave	70	34.0	36.0	15	9.0	-0.03	C
	Mt Auburn St opp Coolidge Ave	Mt Auburn St @ Aberdeen Ave	51	39.0	12.0	14	2.8	4.07	B
	Mt Auburn St @ Aberdeen Ave	Mt Auburn St @ Homer Ave	34	32.3	1.7	13	0.4	3.08	A
	Mt Auburn St @ Homer Ave	Belmont St @ Cushing St	17	21.5	0.0	13	0.0	-5.45	A
	Belmont St @ Cushing St	Belmont St @ Sullivan Rd	17	17.0	0.0	13	0.0	3.44	A
Cambridge Line	Belmont St @ Sullivan Rd	Belmont St @ Oxford Ave	17	13.0	4.0	13	0.9	-4.27	A
	Belmont St @ Oxford Ave	Belmont St @ Marion Rd	34	17.0	17.0	13	3.7	4.22	B
	Belmont St @ Marion Rd	Belmont St @ Falmouth St	44	29.9	14.1	13	3.0	2.29	B
	Belmont St @ Falmouth St	Belmont St @ School St	17	17.0	0.0	14	0.0	4.42	A
	Belmont St @ School St	Belmont St @ Payson Rd	26	21.5	4.5	14	1.1	-5.35	A
	Belmont St @ Payson Rd	Belmont St @ Oakley Rd	18	17.0	1.0	14	0.2	-2.45	A
	Belmont St @ Oakley Rd	Trapelo Rd @ Oak Ave	17	17.0	0.0	14	0.0	2.13	A
	Trapelo Rd @ Oak Ave	Trapelo Rd @ Common St - Cushing Square	25	34.5	0.0	13	0.0	1.71	A
	Trapelo Rd @ Common St - Cushing Square	Trapelo Rd opp Poplar St	39	34.7	4.3	15	1.1	-6.63	A
	Trapelo Rd opp Poplar St	Trapelo Rd @ Slade St	26	26.0	0.0	15	0.0	4.79	A
	Trapelo Rd @ Slade St	Trapelo Rd opp Walnut St	18	18.0	0.0	14.5	0.0	6.61	A
	Trapelo Rd opp Walnut St	Trapelo Rd @ Beech St	26	9.0	17.0	12	3.4	14.90	B
	Trapelo Rd @ Beech St	Trapelo Rd @ Hawthorne St	26	8.0	18.0	12	3.6	-2.19	B
	Trapelo Rd @ Hawthorne St	Trapelo Rd @ Waverley St	26	17.0	9.0	12	1.8	-0.47	B
Waverly Square	Trapelo Rd @ Waverley St	Church St @ Lexington St	26	18.0	8.0	9	1.2	4.82	

Route 73 AM Peak– Towards Harvard

Place	Segment Start	Segment End	Median Running Time	Reference Running Time	Excess Running Time	Median Load	Excess Pax Time	Unreliability	Composite Grade
Waverly Square	Church St @ Lexington St	Trapelo Rd @ Sycamore St	30	34.5	0.0	9	0.0	21.39	
	Trapelo Rd @ Sycamore St	Trapelo Rd @ Beech St	26	17.0	9.0	11	1.7	0.58	B
	Trapelo Rd @ Beech St	Trapelo Rd @ Walnut St	26	18.0	7.5	15.5	1.9	1.08	B
	Trapelo Rd @ Walnut St	Trapelo Rd @ Bartlett Ave	26	25.5	0.5	16.5	0.1	3.60	A
	Trapelo Rd @ Bartlett Ave	Trapelo Rd @ Poplar St	26	18.0	8.0	20	2.7	1.46	B
	Trapelo Rd @ Poplar St	Trapelo Rd @ Common St - Cushing Square	26	17.0	9.0	21	3.2	6.00	B
	Trapelo Rd @ Common St - Cushing Square	36 Trapelo Rd	26	26.0	0.0	24.5	0.0	2.10	A
	36 Trapelo Rd	Trapelo Rd @ Belmont St - Benton Square	35	25.5	9.5	25.5	4.0	5.78	B
	Trapelo Rd @ Belmont St - Benton Square	395 Belmont St	17	13.0	4.0	25.5	1.7	0.53	B
	395 Belmont St	Belmont St opp Payson St	17	17.0	0.0	26	0.0	1.51	A
	Belmont St opp Payson St	Belmont St @ Carver Rd	26	13.0	13.0	27	5.9	1.05	C
	Belmont St @ Carver Rd	Belmont St @ Winsor Ave	18	9.0	9.0	28	4.2	3.53	B
	Belmont St @ Winsor Ave	Belmont St @ Woodleigh Rd	18	17.0	1.0	32	0.5	4.32	A
	Belmont St @ Woodleigh Rd	Belmont St @ Templeton Pkwy	34	17.0	17.0	34	9.6	16.26	C
	Belmont St @ Templeton Pkwy	Belmont St @ Prentiss St	30	18.0	12.0	37.5	7.5	-1.87	C
Cambridge Line	Belmont St @ Prentiss St	Belmont @ Brimmer St	26	17.0	9.0	38	5.7	0.44	B
	Belmont @ Brimmer St	Belmont St opp Cushing St	17	17.0	0.0	41.5	0.0	2.58	A
	Belmont St opp Cushing St	Mt Auburn St opp Homer Ave	69	36.8	32.2	44	23.6	24.28	D
	Mt Auburn St opp Homer Ave	Mt Auburn St @ Aberdeen Ave	18	13.0	5.0	49	4.1	77.70	C
	Mt Auburn St @ Aberdeen Ave	Mt Auburn St @ Coolidge Ave	143	46.7	96.3	49	78.6	124.29	F
	Mt Auburn St @ Coolidge Ave	Mt Auburn St opp Traill St	69	34.5	34.5	48.5	27.9	22.46	E
	Mt Auburn St opp Traill St	Mt Auburn St @ Mt Auburn Hospital	26	26.0	0.0	48.5	0.0	1.19	A
	Mt Auburn St @ Mt Auburn Hospital	Mt Auburn St opp Sparks St	26	17.5	8.5	48.5	6.9	4.70	B
	Mt Auburn St opp Sparks St	Mt Auburn St @ Brewer St	78	48.8	29.2	48.5	23.6	3.16	D
	Mt Auburn St @ Brewer St	Mt Auburn St @ University Rd	43	24.9	18.1	48.5	14.7	1.72	C
Harvard Square	Mt Auburn St @ University Rd	Harvard Upper Busway @ Red Line	26	26.0	0.0	46	0.0	-3.01	

Route 69

MBTA route 69 extends 2.3 miles between Harvard Holyoke Gate and Lechmere station via Cambridge Street. The entire route is in the City of Cambridge. Service is provided every 17 to 20 minutes in peak periods.

Results for Route 69

Composite Grade Summary:

The only segment rated D in both the AM and PM peaks is Norfolk St to Prospect St, which is primarily an issue with XPT.

Composite Grade PM Peak:

In the PM peak, the worst composite grades (E) are in both directions; between Fayette St and Hampshire St in the eastbound direction (from Harvard) and between Cambridge St and Broadway opposite the Fogg Museum in the westbound direction (toward Harvard). In both cases, this is due to travel time MOEs rather than the unreliability MOE. There are also two segments with composite grades of D in the westbound direction, including Norfolk St to Prospect St and Springfield St to Fayette St, both of which rank worst in XPT.

Composite Grade AM Peak:

In the AM peak, the worst composite grades are D and exist in both directions. In the eastbound direction (from Harvard), the Johnston Gate to Prescott St and Norfolk St to Windsor St are D, the first being due to XRT and XPT and the second to unreliability. In the westbound direction (to Harvard), the Norfolk St to Prospect St segment is a D, due to the XPT rating.

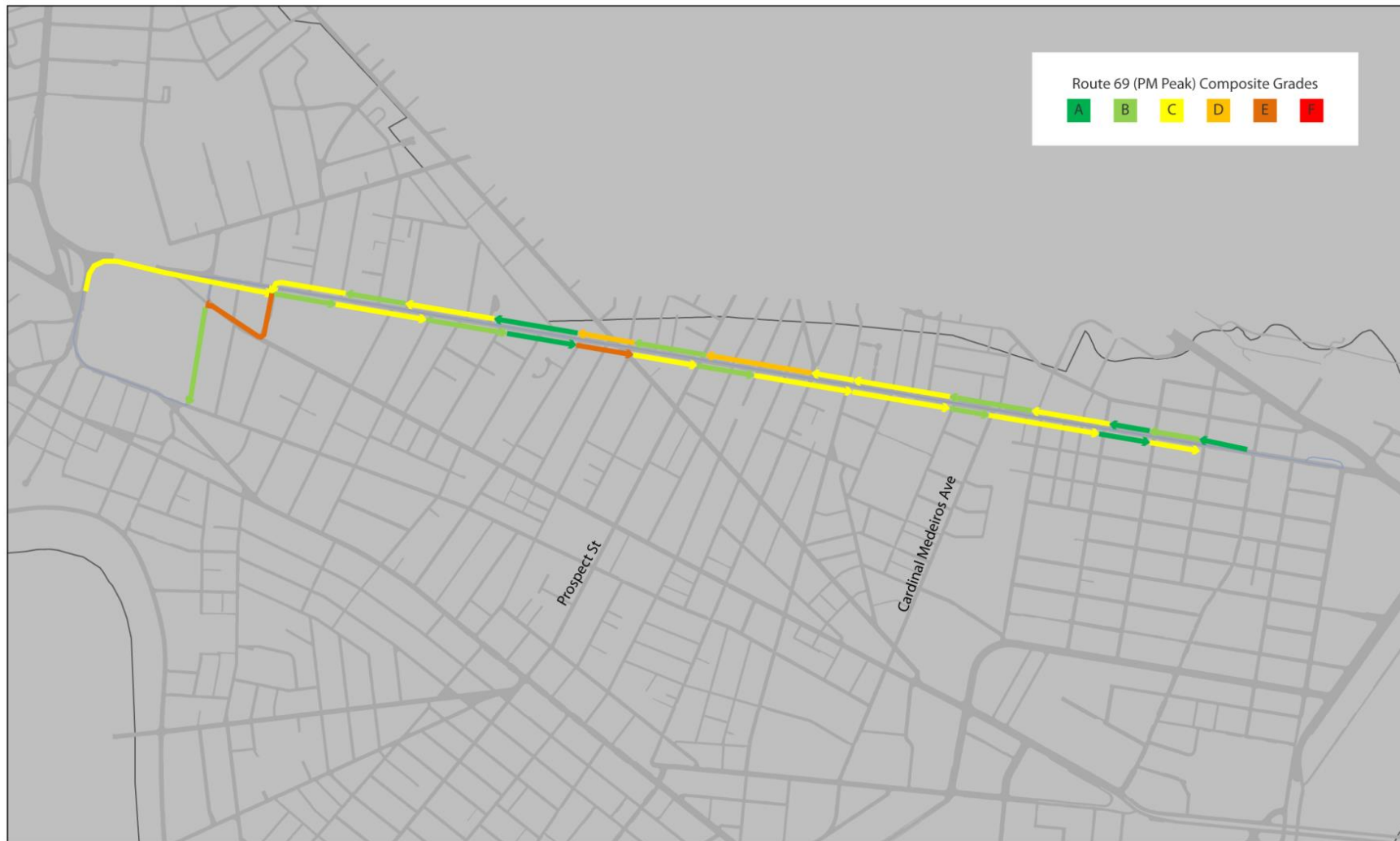
Other MOE Ratings:

In both directions and both peaks, often when composite grades are C or better, XPT ratings are D. This is likely due to the fact that this route is busy (has higher passenger loads) in both directions in both peaks. There is not a prevailing peak commuting direction.

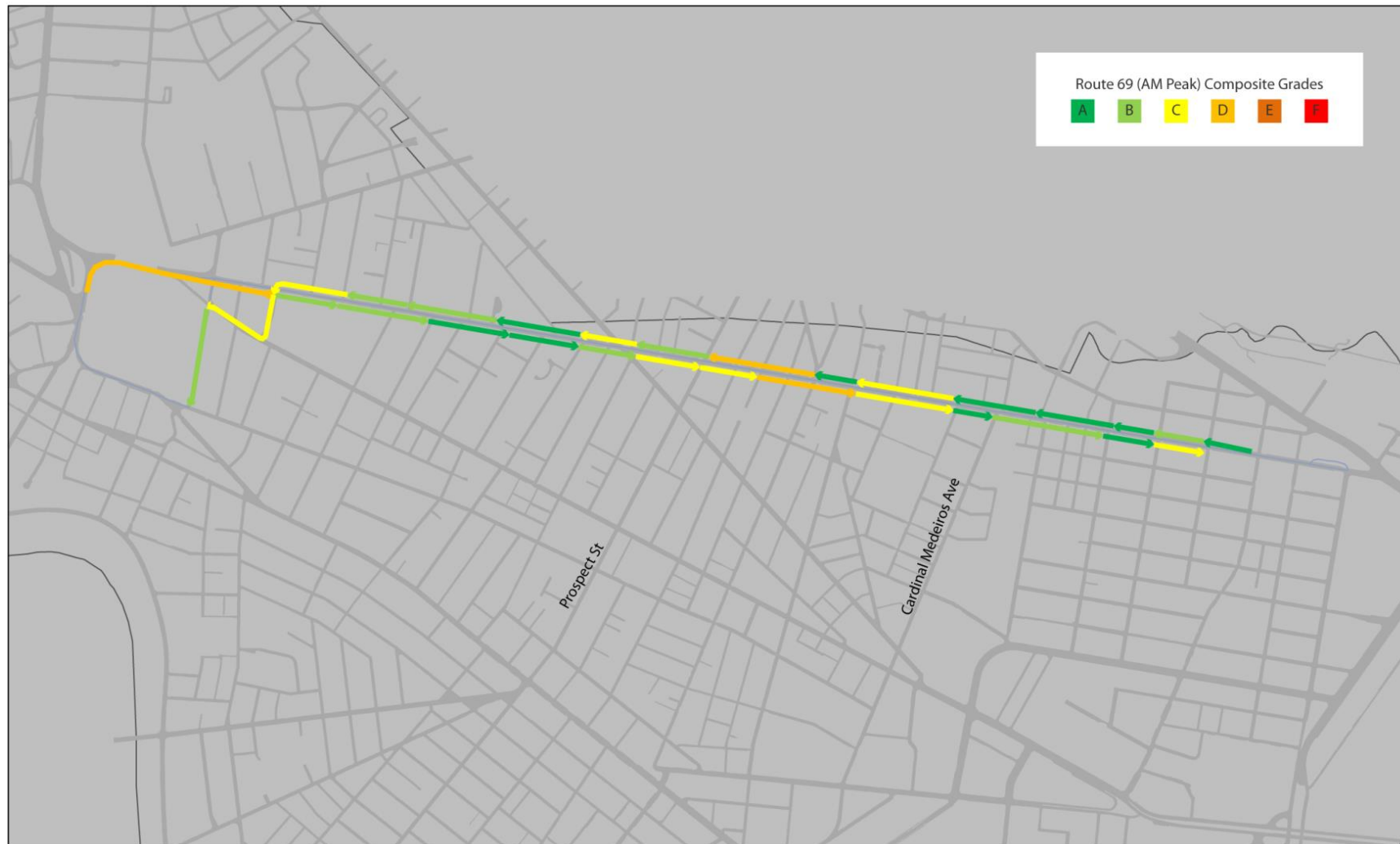
In the PM peak, there are additional unsatisfactory (D) XPT ratings on segments including Johnston Gate to Prescott St, Hampshire St to Prospect St, and Norfolk St to Windsor St in the eastbound direction and Windsor St to Norfolk St in the westbound direction.

In the AM peak, there are additional unsatisfactory (D) XPT ratings on segments including Windsor St to Berkshire St segment in the eastbound direction and the Springfield St to Fayette St segment in the westbound direction.

Route 69 PM Peak



Route 69 AM Peak



Route 69 PM PEAK – From Harvard

Place	Segment Start	Segment End	Median Running Time	Reference Running Time	Excess Running Time	Median Load	Excess Pax Time	Unreliability	Composite Grade
Harvard Square	Massachusetts Ave @ Holyoke St	Massachusetts Ave @ Johnston Gate	44	32.9	10.6	13	2.3	21.06	
	Massachusetts Ave @ Johnston	Cambridge St @ Prescott St	78	39.0	38.5	21.5	13.8	9.29	C
	Cambridge St @ Prescott St	Cambridge St @ Trowbridge St	34	26.0	8.0	24	3.2	13.86	B
	Cambridge St @ Trowbridge St	Cambridge St @ Dana St	43	26.0	17.0	23	6.5	4.91	C
	Cambridge St @ Dana St	Cambridge St @ Highland Ave	34	26.0	8.0	27	3.6	0.50	B
	Cambridge St @ Highland Ave	Cambridge St @ Fayette St	18	17.0	1.0	29	0.5	1.04	A
	Cambridge St @ Fayette St	Cambridge St @ Hampshire St	78	25.9	52.1	28	24.3	14.94	E
	Cambridge St @ Hampshire St	Cambridge St @ Prospect St	52	27.9	24.1	31	12.5	18.07	C
	Cambridge St @ Prospect St	Cambridge St @ Norfolk St	35	26.2	8.8	31	4.5	8.09	B
	Cambridge St @ Norfolk St	Cambridge St @ Windsor St	52	34.5	17.5	30	8.8	1.62	C
	Cambridge St @ Windsor St	Cambridge St @ Berkshire St	44	26.0	18.0	26	7.8	1.44	C
	Cambridge St @ Berkshire St	Cambridge St @ Cardinal Medeiros Ave	30	21.8	8.2	25.5	3.5	1.82	B
	Cambridge St @ Cardinal Medeiros Ave	Cambridge St @ Sixth St	52	30.5	21.5	19	6.8	4.82	C
	Cambridge St @ Sixth St	Cambridge St @ Fifth St	26	24.6	1.4	18	0.4	4.00	A
	Cambridge St @ Fifth St	Cambridge St @ Sciarappa St	26	8.0	18.0	17	5.1	-2.58	C
Lechmere	Cambridge St @ Sciarappa St	Lechmere Station - Outbound Side	151	61.8	89.2	16.5	24.5	14.06	

Route 69 PM PEAK – Towards Harvard

Place	Segment Start	Segment End	Median Running Time	Reference Running Time	Excess Running Time	Median Load	Excess Pax Time	Unreliability	Composite Grade
Lechmere	Lechmere Station - Outbound Side	Cambridge St @ Third St	104	49.6	54.4	18	16.3	53.43	
	Cambridge St @ Third St	Cambridge St @ Sciarappa St	26	21.5	4.5	19	1.4	-3.87	A
	Cambridge St @ Sciarappa St	Cambridge St @ Fifth St	18	13.0	5.0	19	1.6	3.53	B
	Cambridge St @ Fifth St	Cambridge St @ Sixth St	17	13.0	4.0	19	1.3	-0.56	A
	Cambridge St @ Sixth St	Cambridge St @ Lambert St	43	26.0	17.0	21	6.0	5.07	C
	Cambridge St @ Lambert St	Cambridge St @ Berkshire St	35	26.0	9.0	24	3.6	1.16	B
	Cambridge St @ Berkshire St	Cambridge St @ Windsor St	43	26.0	17.0	23	6.5	2.57	C
	Cambridge St @ Windsor St	Cambridge St @ Norfolk St	60	32.9	27.1	25	11.3	3.95	C
	Cambridge St @ Norfolk St	Cambridge St @ Prospect St	77	26.2	50.8	24	20.3	15.45	D
	Cambridge St @ Prospect St	Cambridge St @ Springfield St	35	29.6	5.4	23	2.1	0.89	B
	Cambridge St @ Springfield St	Cambridge St opp Fayette St	52	26.2	25.8	20	8.6	17.85	D
	Cambridge St opp Fayette St	Cambridge St @ Camelia Ave	26	26.0	0.0	19	0.0	2.07	A
	Cambridge St @ Camelia Ave	Cambridge St @ Hovey Ave	43	26.0	17.0	20	5.7	0.17	C
	Cambridge St @ Hovey Ave	Cambridge St @ Trowbridge St	35	26.0	9.0	23	3.5	4.11	B
	Cambridge St @ Trowbridge St	Felton St @ Cambridge St	35	21.5	13.5	23	5.2	5.92	C
	Felton St @ Cambridge St	Quincy St @ Broadway opp Fogg Museum	104	37.3	66.7	21	23.3	7.41	E
	Quincy St @ Broadway opp Fogg Museum	Quincy St @ Harvard St	35	25.5	9.5	20	3.2	-3.60	B
Harvard Square	Quincy St @ Harvard St	Massachusetts Ave @ Holyoke St	56	33.7	22.3	19	7.1	11.42	

Route 69 AM PEAK – From Harvard

Place	Segment Start	Segment End	Median Running Time	Reference Running Time	Excess Running Time	Median Load	Excess Pax Time	Unreliability	Composite Grade
Harvard Square	Massachusetts Ave @ Holyoke St	Massachusetts Ave @ Johnston Gate	43	32.9	10.1	3	0.5	38.03	
	Massachusetts Ave @ Johnston	Cambridge St @ Prescott St	86	39.0	47.0	11	8.6	15.32	D
	Cambridge St @ Prescott St	Cambridge St @ Trowbridge St	43	26.0	17.0	11	3.1	10.90	B
	Cambridge St @ Trowbridge St	Cambridge St @ Dana St	43	26.0	17.0	11	3.1	1.39	B
	Cambridge St @ Dana St	Cambridge St @ Highland Ave	26	26.0	0.0	10	0.0	6.34	A
	Cambridge St @ Highland Ave	Cambridge St @ Fayette St	26	17.0	9.0	8	1.2	9.80	A
	Cambridge St @ Fayette St	Cambridge St @ Hampshire St	43	25.9	17.1	9	2.6	14.73	B
	Cambridge St @ Hampshire St	Cambridge St @ Prospect St	52	27.9	24.1	11	4.4	23.13	C
	Cambridge St @ Prospect St	Cambridge St @ Norfolk St	39	26.2	12.8	12	2.6	21.27	C
	Cambridge St @ Norfolk St	Cambridge St @ Windsor St	61	34.5	26.5	12	5.3	40.40	D
	Cambridge St @ Windsor St	Cambridge St @ Berkshire St	61	26.0	35.0	18	10.5	8.76	C
	Cambridge St @ Berkshire St	Cambridge St @ Cardinal Medeiros Ave	26	21.8	4.2	18	1.3	5.63	A
	Cambridge St @ Cardinal Medeiros Ave	Cambridge St @ Sixth St	43	30.5	12.5	19	4.0	-1.63	B
	Cambridge St @ Sixth St	Cambridge St @ Fifth St	26	24.6	1.4	19	0.5	3.62	A
	Cambridge St @ Fifth St	Cambridge St @ Sciarappa St	26	8.0	18.0	19	5.7	1.79	C
Lechmere	Cambridge St @ Sciarappa St	Lechmere Station - Outbound Side	112	61.8	50.2	19	15.9	-2.24	

Route 69 AM PEAK – Towards Harvard

Place	Segment Start	Segment End	Median Running Time	Reference Running Time	Excess Running Time	Median Load	Excess Pax Time	Unreliability	Composite Grade
Lechmere	Lechmere Station - Outbound Side	Cambridge St @ Third St	112	49.6	62.4	10	10.4	34.83	
	Cambridge St @ Third St	Cambridge St @ Sciarappa St	26	21.5	4.5	10	0.8	4.57	A
	Cambridge St @ Sciarappa St	Cambridge St @ Fifth St	26	13.0	13.0	16	3.5	3.73	B
	Cambridge St @ Fifth St	Cambridge St @ Sixth St	9	13.0	0.0	16	0.0	-2.81	A
	Cambridge St @ Sixth St	Cambridge St @ Lambert St	26	26.0	0.0	23	0.0	2.96	A
	Cambridge St @ Lambert St	Cambridge St @ Berkshire St	26	26.0	0.0	27	0.0	4.16	A
	Cambridge St @ Berkshire St	Cambridge St @ Windsor St	43	26.0	17.0	26	7.4	13.87	C
	Cambridge St @ Windsor St	Cambridge St @ Norfolk St	34	32.9	1.1	32	0.6	8.58	A
	Cambridge St @ Norfolk St	Cambridge St @ Prospect St	61	26.2	34.8	32	18.6	1.70	D
	Cambridge St @ Prospect St	Cambridge St @ Springfield St	35	29.6	5.4	34	3.1	7.74	B
	Cambridge St @ Springfield St	Cambridge St opp Fayette St	43	26.2	16.8	33	9.2	4.82	C
	Cambridge St opp Fayette St	Cambridge St @ Camelia Ave	26	26.0	0.0	36	0.0	0.71	A
	Cambridge St @ Camelia Ave	Cambridge St @ Hovey Ave	35	26.0	9.0	35	5.3	-0.36	B
	Cambridge St @ Hovey Ave	Cambridge St @ Trowbridge St	35	26.0	9.0	36	5.4	7.87	B
	Cambridge St @ Trowbridge St	Felton St @ Cambridge St	34	21.5	12.5	21	4.4	2.58	C
	Felton St @ Cambridge St	Quincy St @ Broadway opp Fogg Museum	61	37.3	23.2	20	7.7	28.25	C
	Quincy St @ Broadway opp Fogg Museum	Quincy St @ Harvard St	34	25.5	8.5	17.5	2.5	-19.37	B
Harvard Square	Quincy St @ Harvard St	Massachusetts Ave @ Holyoke St	26	33.7	0.0	16	0.0	4.61	

Route 1

MBTA key route 1 extends 4.8 miles between Harvard/Holyoke Gate and Dudley Station, running along Massachusetts Avenue in Cambridge, past the Massachusetts Institute of Technology, over the Charles River via the Harvard Bridge (aka Mass Ave Bridge) into the City of Boston, then southwest to Dudley Station on the Orange Line via Albany Street and Melnea Cass Boulevard. About 2.2 miles of the route lie in the City of Cambridge. Service operates every seven to nine minutes in each direction in peak periods.

Composite Grade Summary:

In both peaks and in both directions, the most consistent problems in the composite grade arise between Sidney St and Pleasant St/Bigelow St.

Composite Grade PM Peak:

In the PM peak, there are composite grades worse than D in both directions. In the eastbound (from Harvard) direction, the last segment from 84 Massachusetts Avenue to Beacon St is an F, due to XRT and XPT ratings of F and an unreliability rating of D. In addition, Pleasant St to Pearl St has a composite grade of E due primarily to XRT and XPT. Pearl St to Sidney St has a composite grade of D, primarily due to low-ranking (E) XPT and only moderately ranking (C) XRT and unreliability.

In the PM Peak westbound direction, Sidney St to Prospect St has a composite grade of F, primarily due to XRT and XPT. In addition, the upstream segment, Albany St to Sidney St, has a composite grade of D due primarily to a poor (E) XPT.

Composite Grade AM Peak:

The worst composite grade (E) in the AM peak is from 84 Massachusetts Avenue to Beacon St in the eastbound direction (the last segment before the Mass Ave Bridge). In addition, in the eastbound direction, Albany St to 84 Mass Ave has a composite grade of D.

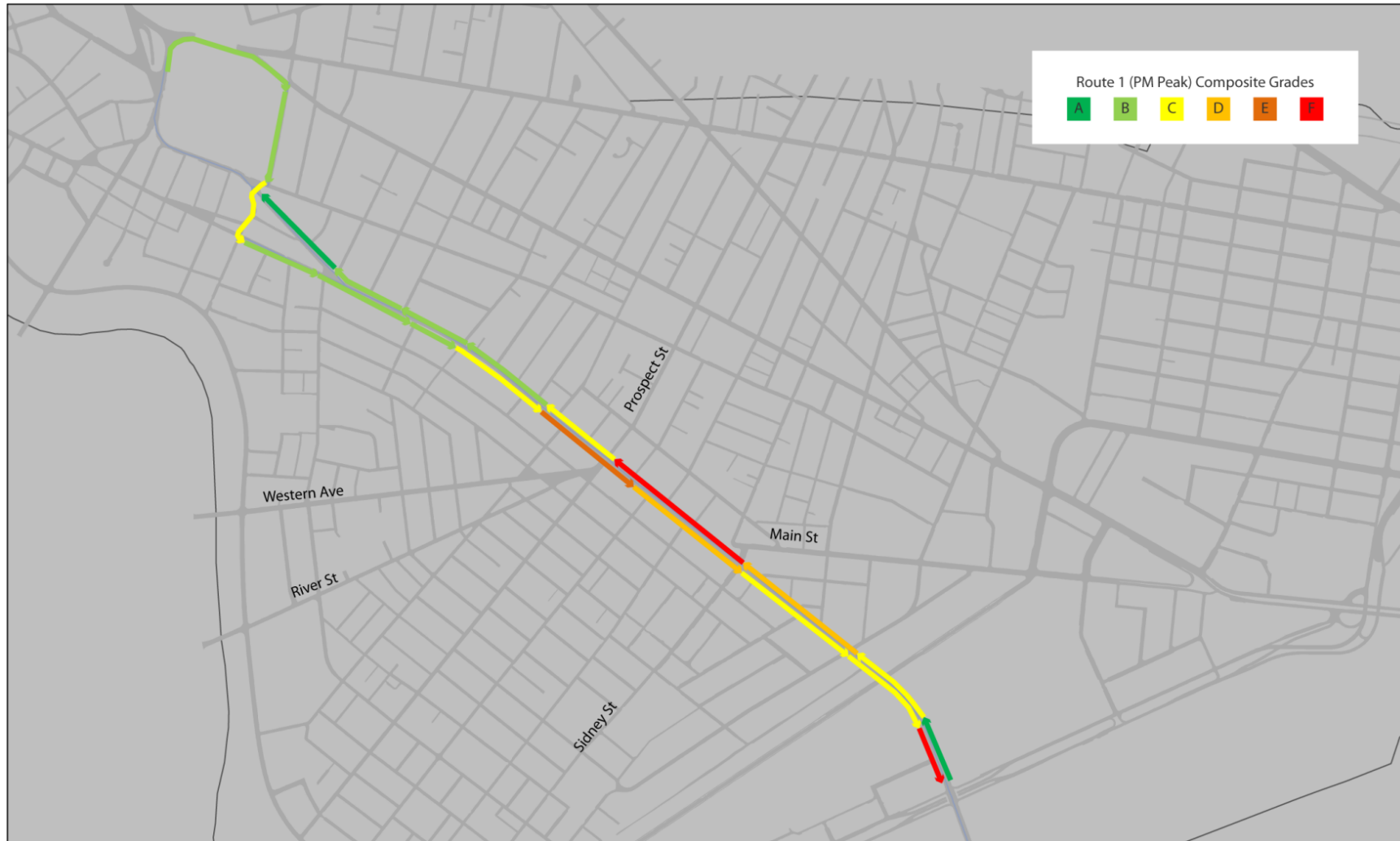
The AM peak has common segments with a composite grade of D in both directions. These segments are from Pleasant to Sidney St in the eastbound direction and from Sidney to Bigelow St in the westbound direction.

In the AM peak, the unreliability rating is always B or better, so issues with the composite grade originate from the XRT and XPT MOEs.

Other MOE Ratings:

In both directions in the PM Peak, in other cases where the composite grade is C, there are ratings of D for XPT. These include segments between Sidney St and 84 Massachusetts Avenue in the eastbound direction, and in the westbound direction, 77 Massachusetts Avenue to Albany St and Prospect St to Bigelow St. Again, there are many riders on route 1, so a small deficiency in XRT can lead to worse ratings for XPT. It can be seen that considerable unreliability is introduced to the PM peak operation between Boylston Street and the Harvard Bridge in Boston. In the direction toward Harvard, this is likely a factor in the perceived overall unreliability in the route's operation in Cambridge.

Route 1 PM Peak



Route 1 AM Peak



Route 1 PM Peak – From Harvard

Place	Segment Start	Segment End	Median Running Time	Reference Running Time	Excess Running Time	Median Load	Excess Pax Time	Unreliability	Composite Grade
Harvard Square	Mass. Ave @ Holyoke St	Mass. Ave @ Johnston Gate	43	32.9	10.1	7	1.2	121.31	
	Mass. Ave @ Johnston Gate	Quincy St @ Broadway opp Fogg Museum	35	26.0	9.0	10	1.5	-1.44	B
	Quincy St @ Broadway opp Fogg Museum	Quincy St @ Harvard St	26	18.0	8.0	12	1.6	3.36	B
	Quincy St @ Harvard St	Mt Auburn St @ DeWolfe St	61	29.0	32.0	13	6.9	3.67	C
	Mt Auburn St @ DeWolfe St	Mt Auburn St @ Putnam Ave	26	18.0	8.0	14	1.9	7.07	B
	Mt Auburn St @ Putnam Ave	Mass. Ave @ Bay St	43	34.5	8.5	17	2.4	-1.45	B
	Mass. Ave @ Bay St	Mass. Ave @ Hancock St	26	17.5	8.5	18.5	2.6	0.88	B
	Mass. Ave @ Hancock St	Mass. Ave @ Pleasant St	43	26.0	17.0	19	5.4	-1.92	C
Central Square	Mass. Ave @ Pleasant St	Mass. Ave @ Pearl St	104	37.5	66.5	19	21.1	0.30	E
	Mass. Ave @ Pearl St	Mass. Ave @ Sidney St	78	41.1	36.9	26	16.0	26.65	D
	Mass. Ave @ Sidney St	Mass. Ave @ Albany St	60	40.7	19.3	30	9.6	1.52	C
	Mass. Ave @ Albany St	84 Mass. Ave	61	35.5	25.5	34	14.5	0.03	C
	84 Mass. Ave	Mass. Ave @ Beacon St	233	78.1	154.9	40	103.3	71.83	F
Cambridge Line	Mass. Ave @ Beacon St	Mass. Ave @ Newbury St	208	40.2	167.8	36	100.7	24.40	F
	Mass. Ave @ Newbury St	Mass. Ave opp Christian Science Ctr	73	43.3	29.7	29	14.4	33.45	D
	Mass. Ave opp Christian Science Ctr	Mass. Ave @ Huntington Ave	69	33.4	35.6	27.5	16.3	7.60	D
	Mass. Ave @ Huntington Ave	Mass. Ave @ Mass. Ave Station	43	25.6	17.4	26.5	7.7	-2.02	C
	Mass. Ave @ Mass. Ave Station	Mass. Ave @ Columbus Ave	43	22.0	21.0	26	9.1	5.71	C
	Mass. Ave @ Columbus Ave	Mass. Ave @ Tremont St	44	31.0	13.0	26	5.6	8.27	C
	Mass. Ave @ Tremont St	Mass. Ave @ Washington St	95	43.6	51.4	26	22.3	28.97	E
	Mass. Ave @ Washington St	Mass. Ave @ Harrison Ave	35	18.0	17.0	22	6.2	10.62	C
	Mass. Ave @ Harrison Ave	Mass. Ave @ Albany St	39	26.0	13.0	22	4.8	28.92	C
	Mass. Ave @ Albany St	Albany St @ Randall St	87	36.4	50.6	25	21.1	1.79	D
	Albany St @ Randall St	Melnea Cass Blvd @ Harrison Ave	35	26.0	9.0	24	3.6	-2.48	B
	Melnea Cass Blvd @ Harrison Ave	Washington St @ Williams St	69	30.6	38.4	24.5	15.7	2.47	C
	Washington St @ Williams St	Washington St @ Ruggles St	26	9.0	17.0	23	6.5	1.93	C
	Dudley Station	Washington St @ Ruggles St	Dudley Station	52	26.6	25.4	20	8.5	3.04

Route 1 PM Peak – Towards Harvard

Place	Segment Start	Segment End	Median Running Time	Reference Running Time	Excess Running Time	Median Load	Excess Pax Time	Unreliability	Composite Grade
Dudley Station	Dudley Station	Washington St opp Ruggles St	43	26.0	17.0	9	2.6	22.43	
	Washington St opp Ruggles St	Washington St @ Melnea Cass Blvd	34	29.3	4.7	10	0.8	16.74	B
	Washington St @ Melnea Cass Blvd	Melnea Cass Blvd @ Harrison Ave	43	24.9	18.1	11	3.3	19.83	B
	Melnea Cass Blvd @ Harrison Ave	Albany St opp Randall St	78	35.0	43.0	11.5	8.2	22.99	D
	Albany St opp Randall St	Mass. Ave @ Albany St	121	38.3	82.7	13	17.9	13.34	E
	Mass. Ave @ Albany St	Mass. Ave @ Harrison Ave	34	26.0	8.0	17	2.3	-0.03	B
	Mass. Ave @ Harrison Ave	Mass. Ave @ Washington St	86	33.1	52.9	28	24.7	9.52	E
	Mass. Ave @ Washington St	Mass. Ave @ Tremont St	78	35.0	43.0	31	22.2	11.09	D
	Mass. Ave @ Tremont St	Mass. Ave @ Columbus Ave	52	26.0	26.0	31	13.4	7.48	C
	Mass. Ave @ Columbus Ave	Mass. Ave @ Mass. Ave Station	43	26.0	17.0	33	9.4	3.47	C
	Mass. Ave @ Mass. Ave Station	Mass. Ave @ St Botolph St	52	21.4	30.6	24.5	12.5	2.65	C
	Mass. Ave @ St Botolph St	Mass. Ave @ Clearway St	69	42.6	26.4	27	11.9	23.19	D
	Mass. Ave @ Clearway St	Mass. Ave @ Newbury St	129	36.3	92.7	29	44.8	45.39	F
	Mass. Ave @ Newbury St	Mass. Ave @ Beacon St	52	38.9	13.1	35.5	7.7	4.90	C
Cambridge Line	Mass. Ave @ Beacon St	Mass. Ave @ Memorial Dr	104	68.9	35.1	38.5	22.5	-4.39	D
	Mass. Ave @ Memorial Dr	77 Mass. Ave	26	26.0	0.0	37	0.0	4.12	A
	77 Mass. Ave	Mass. Ave @ Albany St	43	26.0	17.0	40	11.3	3.81	C
	Mass. Ave @ Albany St	Mass. Ave @ Sidney St	69	42.4	26.6	41.5	18.4	6.00	D
Central Square	Mass. Ave @ Sidney St	Mass. Ave @ Prospect St	177	45.9	131.1	40	87.4	28.49	F
	Mass. Ave @ Prospect St	Mass. Ave @ Bigelow St	61	32.2	28.3	29	13.7	0.46	C
	Mass. Ave @ Bigelow St	Mass. Ave @ Hancock St	35	26.0	9.0	29.5	4.4	-25.05	B
	Mass. Ave @ Hancock St	Mass. Ave @ Dana St	26	17.0	9.0	30	4.5	-0.05	B
	Mass. Ave @ Dana St	Mass. Ave @ Trowbridge St	35	26.0	9.0	26	3.9	-3.29	B
	Mass. Ave @ Trowbridge St	Mass. Ave @ Bow St	26	26.0	0.0	20	0.0	2.66	A
Harvard Square	Mass. Ave @ Bow St	Mass. Ave @ Holyoke St	34	22.0	12.0	19	3.8	-17.27	

Route 1 AM Peak – From Harvard

Place	Segment Start	Segment End	Median Running Time	Reference Running Time	Excess Running Time	Median Load	Excess Pax Time	Unreliability	Composite Grade
Harvard Square	Mass. Ave @ Holyoke St	Mass. Ave @ Johnston Gate	35	32.9	2.1	6	0.2	25.51	
	Mass. Ave @ Johnston Gate	Quincy St @ Broadway opp Fogg Museum	35	26.0	8.5	7.5	1.1	10.33	B
	Quincy St @ Broadway opp Fogg Museum	Quincy St @ Harvard St	25	18.0	7.0	11	1.3	0.50	A
	Quincy St @ Harvard St	Mt Auburn St @ DeWolfe St	69	29.0	40.0	11.5	7.7	7.22	C
	Mt Auburn St @ DeWolfe St	Mt Auburn St @ Putnam Ave	18	18.0	0.0	12	0.0	6.66	A
	Mt Auburn St @ Putnam Ave	Mass. Ave @ Bay St	35	34.5	0.5	16	0.1	0.34	A
	Mass. Ave @ Bay St	Mass. Ave @ Hancock St	26	17.5	8.5	20.5	2.9	-0.96	B
	Mass. Ave @ Hancock St	Mass. Ave @ Pleasant St	35	26.0	9.0	24.5	3.7	4.53	B
Central Square	Mass. Ave @ Pleasant St	Mass. Ave @ Pearl St	86	37.5	48.5	27	21.8	17.39	D
	Mass. Ave @ Pearl St	Mass. Ave @ Sidney St	69	41.1	27.9	37	17.2	7.03	D
	Mass. Ave @ Sidney St	Mass. Ave @ Albany St	61	40.7	19.8	38.5	12.7	4.68	C
	Mass. Ave @ Albany St	84 Mass. Ave	61	35.5	25.5	39.5	16.8	2.77	D
	84 Mass. Ave	Mass. Ave @ Beacon St	121	78.1	42.9	39	27.9	2.17	E
Cambridge Line	Mass. Ave @ Beacon St	Mass. Ave @ Newbury St	104	40.2	63.8	37.5	39.9	25.84	E
	Mass. Ave @ Newbury St	Mass. Ave opp Christian Science Ctr	87	43.3	43.7	31	22.6	5.97	D
	Mass. Ave opp Christian Science Ctr	Mass. Ave @ Huntington Ave	86	33.4	52.6	28	24.5	13.55	E
	Mass. Ave @ Huntington Ave	Mass. Ave @ Mass. Ave Station	52	25.6	26.4	28	12.3	7.39	C
	Mass. Ave @ Mass. Ave Station	Mass. Ave @ Columbus Ave	34	22.0	12.0	38	7.6	4.26	C
	Mass. Ave @ Columbus Ave	Mass. Ave @ Tremont St	39	31.0	8.0	38	5.1	15.49	C
	Mass. Ave @ Tremont St	Mass. Ave @ Washington St	95	43.6	51.4	38.5	33.0	8.76	E
	Mass. Ave @ Washington St	Mass. Ave @ Harrison Ave	44	18.0	26.0	36	15.6	7.38	C
	Mass. Ave @ Harrison Ave	Mass. Ave @ Albany St	26	26.0	0.0	19	0.0	0.44	A
	Mass. Ave @ Albany St	Albany St @ Randall St	86	36.4	49.6	12	9.9	7.13	D
	Albany St @ Randall St	Melnea Cass Blvd @ Harrison Ave	39	26.0	13.0	10	2.2	5.61	B
	Melnea Cass Blvd @ Harrison Ave	Washington St @ Williams St	69	30.6	38.4	10	6.4	-9.84	C
	Washington St @ Williams St	Washington St @ Ruggles St	26	9.0	16.5	9.5	2.6	-4.97	B
	Dudley Station	Washington St @ Ruggles St	Dudley Station	44	26.6	16.9	8	2.3	49.01

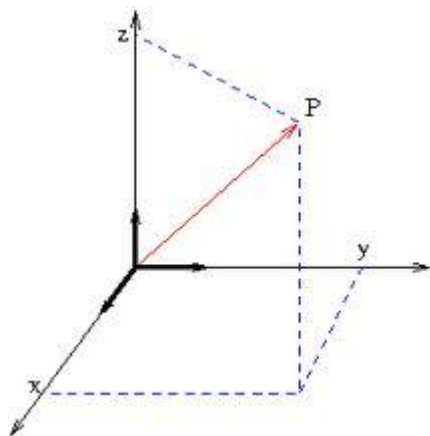
Route 1 AM Peak – Towards Harvard

Place	Segment Start	Segment End	Median Running Time	Reference Running Time	Excess Running Time	Median Load	Excess Pax Time	Unreliability	Composite Grade
Dudley Station	Dudley Station	Washington St opp Ruggles St	51	26.0	25.0	18	7.5	30.68	
	Washington St opp Ruggles St	Washington St @ Melnea Cass Blvd	52	29.3	22.7	18	6.8	22.96	C
	Washington St @ Melnea Cass Blvd	Melnea Cass Blvd @ Harrison Ave	44	24.9	19.1	18	5.7	7.66	C
	Melnea Cass Blvd @ Harrison Ave	Albany St opp Randall St	60	35.0	25.0	18	7.5	11.27	C
	Albany St opp Randall St	Mass. Ave @ Albany St	86	38.3	47.7	17	13.5	19.49	D
	Mass. Ave @ Albany St	Mass. Ave @ Harrison Ave	26	26.0	0.0	15	0.0	6.32	A
	Mass. Ave @ Harrison Ave	Mass. Ave @ Washington St	70	33.1	36.4	16	9.7	10.12	D
	Mass. Ave @ Washington St	Mass. Ave @ Tremont St	87	35.0	52.0	20	17.3	13.86	D
	Mass. Ave @ Tremont St	Mass. Ave @ Columbus Ave	43	26.0	17.0	22	6.2	0.26	C
	Mass. Ave @ Columbus Ave	Mass. Ave @ Mass. Ave Station	43	26.0	17.0	22.5	6.4	10.61	C
	Mass. Ave @ Mass. Ave Station	Mass. Ave @ St Botolph St	43	21.4	21.6	25.5	9.2	11.11	C
	Mass. Ave @ St Botolph St	Mass. Ave @ Clearway St	69	42.6	26.4	29	12.8	5.74	C
	Mass. Ave @ Clearway St	Mass. Ave @ Newbury St	78	36.3	41.7	30.5	21.2	14.85	D
	Mass. Ave @ Newbury St	Mass. Ave @ Beacon St	60	38.9	21.1	36	12.6	8.79	C
Cambridge Line	Mass. Ave @ Beacon St	Mass. Ave @ Memorial Dr	95	68.9	26.1	38.5	16.8	11.63	D
	Mass. Ave @ Memorial Dr	77 Mass. Ave	26	26.0	0.0	35	0.0	1.11	A
	77 Mass. Ave	Mass. Ave @ Albany St	35	26.0	9.0	33	5.0	4.92	B
	Mass. Ave @ Albany St	Mass. Ave @ Sidney St	61	42.4	18.6	25	7.7	4.45	C
Central Square	Mass. Ave @ Sidney St	Mass. Ave @ Prospect St	95	45.9	49.1	21.5	17.6	12.07	D
	Mass. Ave @ Prospect St	Mass. Ave @ Bigelow St	60	32.2	27.8	19	8.8	11.27	D
	Mass. Ave @ Bigelow St	Mass. Ave @ Hancock St	34	26.0	8.0	19	2.5	-2.13	B
	Mass. Ave @ Hancock St	Mass. Ave @ Dana St	26	17.0	9.0	17	2.6	-24.04	B
	Mass. Ave @ Dana St	Mass. Ave @ Trowbridge St	26	26.0	0.0	15	0.0	1.43	A
	Mass. Ave @ Trowbridge St	Mass. Ave @ Bow St	26	26.0	0.0	13	0.0	0.84	A
Harvard Square	Mass. Ave @ Bow St	Mass. Ave @ Holyoke St	26	22.0	4.0	11.5	0.8	-4.96	

Appendix A

IBI Group developed a composite rating to represent the combination of the three MOEs for running time, travel time, and unreliability. This composite was designed to account for the fact that a simple average of the ratings for each MOE would allow an excellent rating for one MOE to obscure a failing one for another. The importance of all aspects performing well can be reflected by visualizing each MOE as one of three distinct dimensions as shown in the following graphic, with the best possible rating being at the origin, and the worst rating for each MOE being an equal constant distance out on each of the three axes. The composite rating would in effect be proportional to the total *distance* in three-dimensional space from the origin. A very poor performance on only one of the three MOEs would have a more than proportional effect on the composite grade.

Example of a Distance in Three Dimensions



For example, consider letting the x axis represent a segment's XRT, y represent its XPT, and z represent its SCDTT. For an example route segment rated 'C' (yellow, the third of the 6 possible values) for each of the three MOEs would have a distance¹⁰ of $\sqrt{3^2 + 3^2 + 3^2}$ from the origin.

In order to have six composite grades that would have a number of ratings and letter grades comparable to individual MOEs, the distances for each segment were multiplied by the ratio of 6 (the worst possible composite grade) to the distance for the a segment with the worst rating for all three MOEs. *i.e.* $\sqrt{6^2 + 6^2 + 6^2}$. For the example above, the result is 3.0, resulting in a composite grade of 'C' (yellow).

¹⁰ In accordance with the formula for Euclidean distance in three dimensions.

The case of a different example route segment with the ratings 2 ('B'), 2 ('B'), and 5 ('E') shows how the result of the composite method would differ from simple averaging, which would return the same rating as for the '3'3'3' case above. The corresponding distance in Euclidean space is $\sqrt{2^2 + 2^2 + 5^2}$, resulting in a composite rating of 'D' (orange). In effect the very poor performance on only one MOE can bring the overall rating down further than a simple arithmetic average.